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MISCELLANEOUS.

Collections received 123, 257, 417, 563

ERRATA.

- Page 196, line 2, for "H. K. Barnard" read "K. H. Barnard"
 „ 326, line 26, for "Anoma" read "Anona"
 „ 391, line 11, for "buolianae" read "buolianus"
 „ 395, 5 lines from end, for "nine pairs" read "ten pairs"
 „ 397, line 13, for "Pamene" read "Pammene"
 „ 410, lines 9, 15, for "80° C." read "80° F."
 „ 478, line 20 & 480, line 1, for "Pityogenes" read "Pityophthorus"
 „ 485, line 30, for "utetheisae, sp. n.," read "guyanensis Cam."

IMPERIAL BUREAU OF ENTOMOLOGY.

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SOME ASPECTS IN THE BIOLOGY OF LONGICORN BEETLES.

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Chief Entomologist, Swedish Forestry Research Institute.

The Longicorn beetles comprise numerous species that are highly injurious both to growing trees and to timber, and some excellent papers have been published dealing either with important species and the methods of preventing their damage (Brooks, 1920) or giving a survey of a particular fauna (Craighead, 1923). Nevertheless, there are some rather important features of the life-history of these beetles that seem to have attracted only scant attention, and which have hitherto not been subjected to a systematic analysis. The purpose of this paper is to call attention to these neglected features and to give a short survey of the meagre and scattered information that we have about them, in order to stimulate further study, which seems warranted from both a theoretical and a practical point of view.

Oviposition.

Leaving aside those differences in oviposition that are due to the choice of different host-plants, varying dimensions of the trees, etc., we may divide the Longicorns into two groups, those that oviposit in or under the bark and those that oviposit in cracks in the wood.

Most of the genera belong to the first group, as, for instance, *Monochamus*, *Acanthocinus*, *Rhagium*, *Tetropium* and *Callidium*. Their dependence upon the bark may be of a higher or a lower degree. Some, e.g., *Rhagium* and *Acanthocinus*, which make their entire larval mine under the bark, obviously require this protection throughout their life; other species, which only in early life live under the bark and later on enter the wood, require only small portions of bark for oviposition, because the larva enters the wood earlier when the bark covering is insufficient. To the latter group belong *Callidium* and *Monochamus*.

Some species, however, are quite independent of the bark, ovipositing as they do in cracks of the wood, and are therefore liable to attack timber in houses or fence-posts, e.g., *Hylotrupes bajulus* and *Leptura testacea*. Such insects have often very long ovipositors, with the help of which they are able to insert the eggs fairly deeply into the cracks.

Those species that only lay their eggs on the bark use several methods, the occurrence of which in the different genera is very little known. It has hitherto been possible to distinguish between the following three methods.

1. The females do not gnaw any slits in the bark but lay their eggs in crevices in the bark (fig. 1,A), with the help of their long ovipositors. The shape of the head of the beetles is not adapted for gnawing into the bark; it is not vertical and does not taper towards the mouth, nor are the antennae inserted far up on the frons

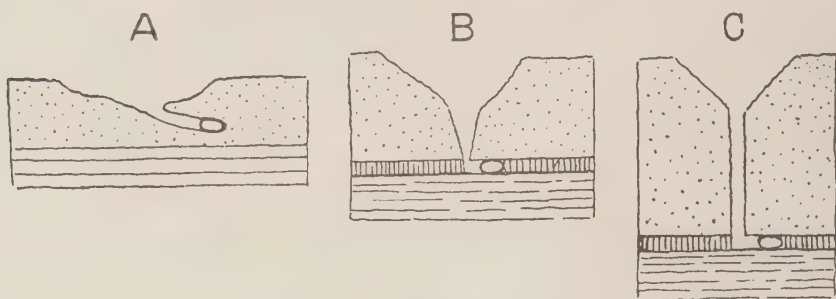


Fig. 1. Three different types of oviposition in Longicorn beetles: A, no slit is gnawed, but the egg is laid in a crevice in the bark with the aid of the ovipositor; B, a funnel-shaped slit is gnawed through the bark to the cambium by the mandibles only; C, a funnel is excavated through the bark, partly with the mandibles, partly with the pygidium, which is used as a drill.

(fig. 2), as is the case in those species that gnaw funnels in the bark. On the other hand, the last segment of the abdomen is conical and the ovipositor is long and telescopically exsertile. I have not been able to watch any species of this group laying eggs, but a very close examination of many pieces of bark attacked by *Tetropium castaneum* has failed to reveal any slits. The numerous longitudinal streaks of resin found on the bark are obviously the result of the activity of the



Fig. 2. Head of *Tetropium*, *Acanthocinus*, and *Monochamus* (from left to right).

young larvae when entering the cambium. The shape of the abdomen of the females suggests, however, the possibility of the latter boring a little into the bark (fig. 3). How helpless the beetles are with their mandibles will further be seen from the methods the larvae employ to facilitate their emergence (cf. p. 5). Many genera belong to this group, for instance, *Tetropium*, *Callidium*, and *Clytus*.

2. The females gnaw a more or less funnel-shaped slit in the bark, and this funnel is deepened further by the action of the tip of the abdomen, which is used as a kind of drill. In this way a hole may be excavated even through bark 15 mm. thick, the upper part (about 4 mm. deep) being funnel-shaped (fig. 1,C) and the remainder (about 11 mm. deep) cylindrical. The lower part of the head of the beetle tapers gradually downwards, the frons is slightly concave, and the antennae are inserted at

the top of the frons (fig. 2), all these being structural features that enable the female to gnaw as deep a slit as possible in the bark. The last abdominal segment is long, narrow, and pointed like the blade of a knife.

3. The females gnaw a deep slit in the bark, which penetrates to the cambium, but are devoid of any exsertile ovipositor, nor is the last abdominal segment pointed. The head is even better adapted for gnawing slits in the bark than in group 2, and its frons is concave. Many Longicorns probably belong to this group, such as *Saperda* and *Monochamus*, but at present we know very little about the prevalence of this method. Personally I have only been able to study it in *Monochamus sutor*.

Larval Tunnels and Pupal Chambers.

As I have pointed out elsewhere (1918, pp. 222-227), it is possible to distinguish between at least three types of larval tunnels and pupal chambers in the Longicorns.

1. Both larval tunnels and pupal chambers are between the bark and the wood : *Rhagium*, etc.

2. Larval tunnels between the bark and the wood ; pupal chambers in the wood : *Tetropium*, *Callidium*, *Clytus*, etc.

3. Larval tunnels running partly between the wood and the bark, but for the greater part in the wood, where also the pupal chambers are excavated : *Monochamus*.



Fig. 3. Apex of abdomen of *Tetropium castaneum*, *Acanthocinus aedilis*, with ovipositor, and *Monochamus sutor*, without elytra (from left to right).

Many species have not, however, quite fixed habits in this respect, but are able to modify the position of both the larval tunnel and the pupal chamber according to external factors. Of these we may discern at least three on the basis of the data available, viz., the quality of the wood, the thickness of the bark, and the size of the tree.

1. The influence exerted by the quality of the wood attacked is beautifully illustrated by the investigations into *Clytus rusticus* published by the author (1922, pp. 361-365). When this species attacks the hard wood of birch, the larval tunnels run throughout their entire length in the cambium, only the pupal chambers being excavated in the wood (*l.c.* fig. 4, c). When, on the other hand, this species attacks the soft wood of aspen the larval tunnels penetrate deeply into the wood.

2. The thickness of the bark greatly influences, at least in some instances, the choice of the site for the pupal chamber. Kemner points out (1922, pp. 90-92) that *Acanthocinus aedilis*, which ordinarily makes its pupal chamber under the bark, sometimes excavates it in the wood, and he suggests that this happens when the bark is too thin and loose to protect the larva. This theory assumes that the larva is positively thigmotropic, which may be true.

In another instance (*Clytus arcuatus*) the thickness of the bark deeply influences the behaviour of the larva when preparing the pupal chamber, without it being possible to explain this as a thigmotropic reaction, because the bark adheres sufficiently to the trunk to support the larva. The larva of this species makes its pupal chamber in the wood of the oak whenever the bark is not more than 10–15 mm. thick (fig. 4) (cf. Trägårdh, 1922, fig. 7, *a-d*); but when, as often happens, the bark is very thick (30–40 mm.), the larva excavates the pupal chamber in the bark (fig. 4), so as to leave only a thin layer as a protection for the pupa, which the adult beetle has to gnaw through before emerging.

3. The size of the tree also plays an important part in determining the direction of the larval tunnels in those species which burrow in the wood. Especially in

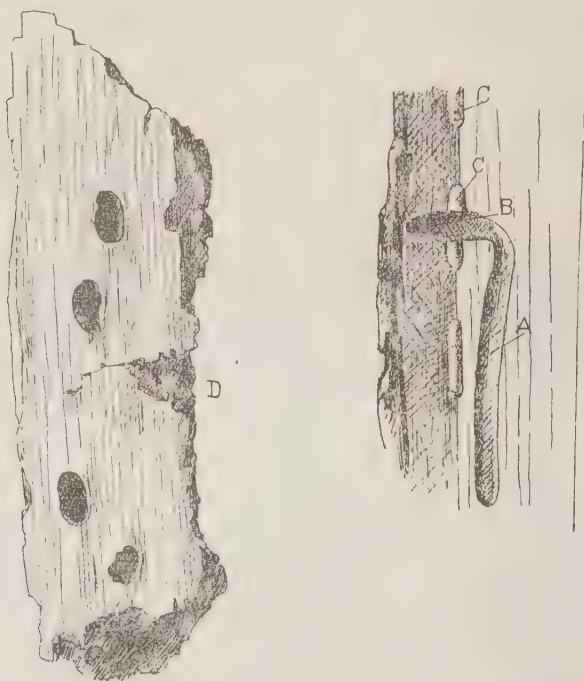


Fig. 4. Pupal chambers of *Clytus arcuatus* in oak: A, section of chamber in wood; B, funnel in the bark; C, larval tunnels filled with frass; D, pupal chambers in bark.

Monochamus sutor this influence is very evident, as already pointed out by the author (1923, pp. 3–4). In the autumn the larva enters the wood in a radial direction and penetrates to about 7 cm. If the diameter of the trunk does not greatly exceed twice this distance, the larva will hibernate in the centre of the trunk. Hence, when continuing in the spring to burrow in the wood, the larva has to cover at least the same distance to reach the surface of the trunk anywhere, and consequently this part of the tunnel and the pupal chamber may run in any direction (fig. 5, A).

But if the diameter of the tree is considerably greater than 14 cm. the tunnel takes quite another shape, the out-going part of it always turning towards the same

side of the trunk as the in-going part, so that the whole tunnel forms a U (fig. 5, B). This difference in the shape of the tunnels according to the diameter of the trunk is quite constant, and it is evident that the larva is in some way able to detect the shortest way to the periphery. It is probably guided by its perception of the different temperatures in the different parts of the trunk. In smaller trees with a diameter not exceeding 14–16 cm. at breast height the larva hibernates in the centre of the trunk; hence in the spring when the wood is warmed by the increasing temperature of the air this warming is almost uniform all round the larva, which makes its exit tunnel in any direction. In bigger trees the distance from the hibernating larvae to the surface may be 7–8 cm. in one direction and 20 cm. in the opposite. Consequently the wood must be warmed more quickly along the shorter radius, and if the larva reacts positively towards a higher temperature, it must turn towards the warmer side.

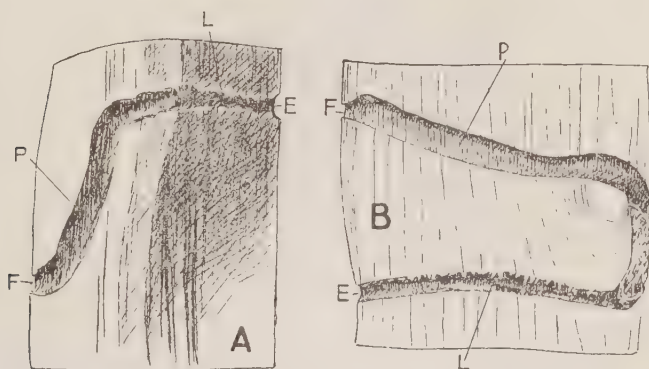


Fig. 5. Larval tunnels and pupal chambers of *Monochamus sutor*: A, in a trunk about 14 cm. in diameter; B, in a considerably thicker trunk; e, entrance hole; l, larval tunnel before hibernation; p, pupal chamber; f, flight hole.

In this connection it is noteworthy that in Longicorn larvae chordotonal organs have been described (Hess, 1917) which have been interpreted as organs of hearing. Even in the larva of *Monochamus sutor* they are present on the first 8 abdominal segments. One may, however, feel justified in asking of what use organs of hearing would be to larvae which burrow slowly in the wood and are unable to escape any approaching danger of which a noise would warn them. Is it not possible that these organs are the means employed by the larva to register the change of temperature in the wood?

The Emergence of the Adult Beetle.

The result of the ability of the pine-sawyer to alter the direction of the out-going part of the tunnel is to facilitate greatly the emerging of the adult. The same result is achieved in other ways by other species, which also in a remarkable degree are able to adapt themselves to different conditions.

If we examine closely the inner surface of a piece of bark of a spruce attacked by *Tetropium castaneum* (fig. 6) we notice that the end of the larval tunnel is fairly broad and filled by a closely packed whitish mass of frass and excrement. This part of the

tunnel covers the entrance to the characteristic pupal chamber excavated by the larva in the wood, and contiguous to it we always find an oval aperture filled with a brown powder. This aperture is the mouth of a burrow through the bark, which almost reaches its exterior surface, only a thin layer being left, which the adult beetle gnaws through on emerging (fig. 6, D). Everything necessary for the convenience of the adult is done, and the behaviour of the larva seems very purposeful. But it does not seem necessary to presume the existence of any special instincts in the larva,



Fig. 6. Inner surface of spruce bark with galleries made by *Tetropium castaneum*: A, larval gallery filled with brown frass; B, terminal part of larval gallery filled with whitish frass produced when the pupal chamber was excavated in the wood; C, entrance to tunnel gnawed by the larva before pupation; D, longitudinal section through the funnel.

because the burrow is easily explained, if we assume that the full-grown larva, after finishing the excavation of the pupal chamber, needs some food consisting of bark, a substance on which it fed during its earlier development.

In the case of *Clytus arcuatus* we find a similar burrow, but only when the thickness of the bark does not exceed 15 mm., in which case the pupal chamber is excavated in the wood. When, on the other hand, the bark is thicker, the pupal chamber is invariably excavated in the bark itself close to the surface.

Feeding Habits of the Adults.

Our knowledge of the feeding habits of adult Longicorns is mainly due to Craighead and Kemner, but the papers by Brooks, Hess, and Gunn contain much important information on this point, and Heintze (1925) has given a comprehensive survey of the feeding habits of the LEPTURINI.

On the basis of our present knowledge of their feeding habits we may divide the Longicorns into three groups.

1. Food consisting of pollen and other parts of flowers. Head and prothorax tapering gradually forward so as to allow the beetles to insert them into the flowers: LEPTURINI and some CERAMBYCINI and LAMIINI (Craighead, Kemner, Heintze).

2. Food consisting of the green parts of the plants, such as leaves or needles : *Saperda carcharias* (Kemner), *Saperda candida* (Brooks).

3. Food consisting of the bark of twigs and branches and leaf-stems and leaf-ribs : *Saperda candida* (Brooks), *Monochamus galloprovincialis* (Rimsky-Korsakov, in a paper read at the International Entomological Congress at Ithaca in 1928).

There are nevertheless many species of whose feeding habits we know nothing, and which have therefore provisionally been relegated to a fourth group, which are suspected of not feeding during their short adult stage.

It is in this connection, however, worth while to recall how our knowledge regarding the feeding habits of the adult bark-beetles (SCOLYTIDAE) has progressed along almost the same lines.

The bark-beetles are generally divided into three groups according to their manner of feeding.

1. Feed under the bark of the same tree in which they have passed their development as larvae and pupae : IPINI and most of the other bark-beetles.

2. Feed on the shoots or on other parts of other vigorous trees : *Blastophagus*.

3. No feeding in the adult stage : SCOLYTINI.

In at least one instance it has been proved (Spessivtseff) that a *Scolytus*, *S. laevis*, does and must feed in order to reach sexual maturity. This species feeds at the base of the buds and the leaf-stalks for only a few days, causing damage that is easily overlooked. It does not seem improbable that the other species referred to the 3rd group also feed, although in an inconspicuous way, and that this has consequently been overlooked.

It is also possible that in many of the Longicorns that are not pollen-feeders the feeding is of a rather inconspicuous nature and hence has been overlooked. Especially in those instances where the females are known to gnaw slits in bark, it seems impossible to reject the idea that they may at the same time do some feeding on the bark. In order to investigate this, I have subjected the alimentary canal of the females of both *Monochamus sutor* and *Acanthocinus aedilis* to an investigation. In both instances the hind intestine proved to contain numerous particles of bark. It is therefore necessary to recognise as a fourth group of the Longicorns those that feed on the bark of the trunks. Whether this feeding is done when they make their way through the thin wall of bark left by the larva when excavating the pupal chambers, or takes place when the slits for oviposition are gnawed, remains yet to be settled. And feeding experiments accompanied by anatomical investigation of the development of the sexual organs are further necessary for the purpose of ascertaining the importance of the feeding. Feeding accompanying egg-laying does, as a matter of fact, occur fairly often amongst insects. Thus Bischoff (1927, pp. 85-86) records many instances in which parasitic Hymenoptera puncture the skin of their hosts and devour the drops of liquid that emerge, even the males sometimes partaking of the food which the females procure in this way. And amongst the Diptera in the AGROMYZIDAE the females frequently use their ovipositors to wound the leaves where they lay their eggs and lick the juices oozing from the wounds.

No matter whether the Longicorns mentioned above feed, as I personally suspect, when gnawing the slits for their eggs in the bark or consume some bark when they emerge from their pupal chamber, the fact remains that a diet of bark is a regular feature of some Longicorns that were previously not known to feed. If this feeding takes place from the exterior surface when the females oviposit, there is a possibility of making use of this habit by dusting or spraying the timber to be protected with some poisonous substance.

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ON A COLLECTION OF THYSANOPTERA FROM SOUTH AUSTRALIA.

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I am indebted to the Imperial Bureau of Entomology and to Mr. F. Laing, of the British Museum, for submitting to me for classification two small lots of Thysanoptera collected by Messrs. G. Samuel and J. G. Bald, of the Waite Agricultural Research Institute, Glen Osmond, South Australia.

THRIPIDAE.

Hemianaphothrips (Anaphothrips) tersus, sp. n.

Priesner's subgenus *Hemianaphothrips* of the genus *Anaphothrips*, Uzel, includes this species, which has antennae distinctly 9-segmented and no strong hairs on the posterior parts of the pronotum. Being the first of its genus to be described from Australia, these characters alone will distinguish it from the Australian species of *Anaphothrips*.

Holotype ♀: General body-colour pale lemon-yellow, with the pterothorax orange-yellow and the prothorax a little paler orange-yellow. Pale grey lies on the vertex of the head and as an indistinct transverse patch on the mid-dorsal surface of each of abdominal segments II-VI and on the sides of X, which is tipped with brown. Antennal segment I pale yellow, II darker yellowish grey, III intermediate in colour between I and II, IV-IX darker concolorous yellowish brown, except that IV and V are slightly paler at their pedicels. Eyes almost black. Ocelli with bright brownish red pigment. Mouth-cone and ends of tarsi tipped with dark brown. Legs coloured like body. Fore-wing concolorous pale yellowish grey with veins very faintly marked. Hind wing very pale yellowish grey with a slightly darker longitudinal vein. Hairs and ovipositor only little darker than body. The cuticle is coloured pale yellowish grey, and its thicker parts are usually marked with very faint confluent striae.

Measurements in μ : Length (width): Antennal segments I 26 (30), II 34 (28), III 49 (21), IV 46 (20), V 40 (17), VI 43 (20), VII 14 (12), VIII 10 (9), IX 14 (6); total length of antenna 276; head 102 (150); median ocellus 8 (11), lateral 11 (11); eye 60 (36); mouth-cone 138 (136 at base); maxillary palp segments I 18 (7), II 14 (5), III 18 (4); labial palp segments I 3 (5), II 18 (3); prothorax 126 (156-192); pterothorax 180 (252); fore wing 840 (60 at middle); hind wing 732 (42); abdomen 720 (324); ovipositor 216 (108 at base); total length of insect 1056. Length of hairs: ante- and post-oculars 17, on disc of pronotum 17, on abdominal segments II 17-32, IV 20-38, VIII 20-46, IX 87-95, X 32, 87, 98; teeth of comb on VIII 15.

Head considerably retracted into prothorax and with cheeks only slightly curved. Eyes projecting but little, with inner angles rounded and moderate-sized facets and about eight inconspicuous hairs. Anterior ocellar lens little smaller than lateral ocelli and placed closer to them than they are to one another. Each lateral ocellus separated by about the length of its lens from the eye. All hairs inconspicuous and about equal in size: two pairs lying well in front of the ocelli and three pairs across the back of the head. The transverse striae of the occiput are faint.

Antennae 9-segmented, inserted in front below the vertex of the head and closely approximated. Segment I wider than long; II barrel-shaped but more constricted at base, which has a short annulus; III with a short pedicel, then an expansion equal in length to, but twice as wide as, the pedicel, and expanding rather abruptly into the narrow end of the oval body of the segment. It has a strong dorsal and a slight ventral curvature outwards. Segment IV ellipsoid with a short pedicel and having a slight dorsal and a strong ventral curvature outwards; V ovoid with a short

pedicel; VI elongate-ovoid with broad base and sides leading into those of VII-IX, which ends with a fairly blunt apex. Segments I-II are marked with faint transverse striae, III-VI bear each 5-8 rings of exceedingly delicate microtrichia. A forked, curved trichome is present on the dorsal surface of III just posterior to the apex, and another is similarly placed on the ventral surface of IV. All the segments bear a few hairs.

Pronotum with posterior angles distinct and with sides converging towards the anterior. It bears about 14 small scattered hairs and none at the posterior angles or margin. Meso- and meta-thorax of normal structure. Legs with few small hairs; hind tibia with a row of seven stiff, almost colourless hairs along its inner ventral

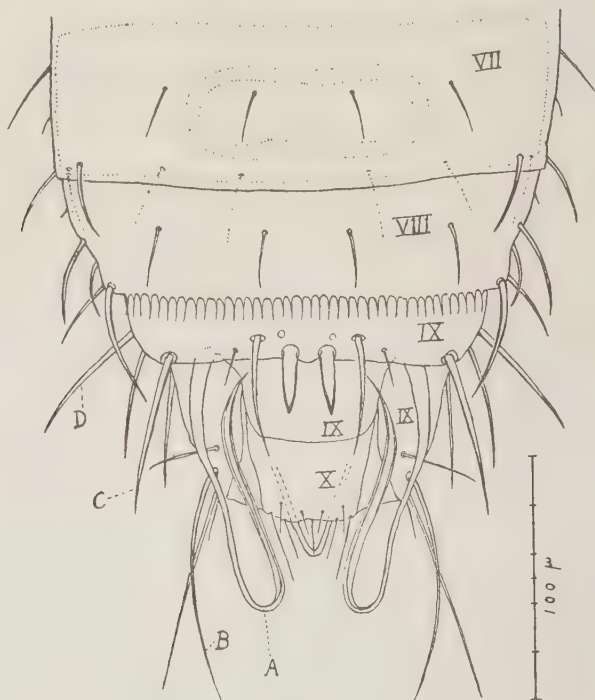


Fig. 1. *Hemianaphothrips tersus*, sp. n., apex of abdomen of male. Sternum VII is shown in dots.

margin and two strong spines at its apex. Fore wing: costa with 30-36 short, 22-24 longer more slender hairs; first vein with 15-19 hairs arranged more or less in three groups of 5-4 hairs near the base, 3-5 hairs just past the fork, and 7-9 scattered at various intervals along the rest of the vein. Second vein 15-20 hairs; alula 5 and 2 hairs. The hairs fringing the hind wing and the posterior margin of the fore wing are normal.

Abdomen of elongate-ovoid shape. Tergum I is hairless, each of terga II-VIII bears a mid transverse row of four delicate hairs and a pair of much stronger hairs on each side. The pleurites bear similar strong hairs, whilst sterna II-VII bear each a row of 4-6 long hairs towards its posterior margin. The posterior margin of VIII bears a continuous comb of 32-38 teeth; IX bears 4 and X 2 pairs of extra long, strong hairs; X is not split dorsally.

Allotype ♂ (fig. 1). Coloration like that of female but a little paler and with

yellowish-brown vesiculae seminales conspicuous internally towards the end of the abdomen, and with the two dorsal spines of abdominal segment IX yellowish brown.

Measurements in μ : Antennal segments I 23 (30), II 32 (26), III 43 (18), IV 43 (19), V 38 (17), VI 40 (17), VII 11 (11), VIII 8 (7), IX 13 (5); total length of antenna 252; head 90 (138); median ocellus 6 (11), lateral 11 (11); eye 54 (33); mouth-cone 108 (132); maxillary palp segments impossible to measure accurately; labial palp segments I 2 (4), II 14 (2.5); prothorax 130 (153-174); pterothorax 162 (228); fore-wing 720 (48); hind wing 648 (36); abdomen 552 (244); penis 126 (72 near base); regions occupied by curved bands of delicate chitin in urosterna III 40 (116), V 43 (116), VII 37 (98), and width of each band is 6; total length of insect 900. Length of hairs: ante- and post-ocular 20-23; prothoracic 15; on abdominal segments II 11-17, IV 17-37, VIII 20-37; IX (see fig. 1) spine 25 (5 near base), hair A 230, B 92, C 65, D 58; X 30; teeth of comb on VIII 12.

Morphology like that of female. Fore-wing costa 25-31 short, 19-22 longer, more slender hairs; first vein with 13-16 hairs arranged as in female; second vein with 13-15 hairs; alula with 5 and 2 hairs. Urosterna III-VII bear each a transverse band of delicate chitin which curves back and then inwards (fig. 1). Abdominal chaetotaxy like that of female, except that VIII bears a comb of about 40 teeth. Besides other hairs IX bears a pair of strong spines dorsally near the middle, and more laterally a pair of strong, very long hairs which pass backwards and then curve forwards and are more or less flattened; X bears 4 pairs of very delicate hairs.

Described from 1 ♀ holotype found on *Cineraria* leaves, Adelaide Botanic Gardens, S. Australia, 25.ix.1929 (*J. G. Bald*), and 22 other females: 17 on *Malva parviflora* leaves, 2 on bean leaves and 3 on marrow leaves, Glen Osmond. Various deformities of the antennae were shown by 2 ♀♀. The ♂ allotype and 2 paratypes were found with females on *Malva parviflora* leaves, Glen Osmond, S. Australia, 30.vii.1928 (*J. G. Bald*).

The holotype and allotype, and paratypes of both sexes are deposited in the British Museum and other paratypes have been returned to the Waite Institute.

A nymph II found on bean leaves, Glen Osmond, 28.ii.1928, almost certainly belongs to this species, but till other specimens are found I do not propose to describe it beyond writing that it is very similar to other nymphs of Priesner's ANAPHOTHIRIPINI, since it is very pale yellow with antennal segments III-VI grey, and with almost all the body hairs pale, stumpy and flattened at the tips. Most of the dorsal abdominal cuticle is raised into transverse rows of minute rounded tubercles, and the posterior margin of IX bears a ring of small tubercles.

Frankliniella insularis (Franklin).

Ten ♀♀, 12 ♂♂ on tomato leaves, and 16 ♀♀, 5 ♂♂, 1 I, 9 II on carnation flowers, Glen Osmond, 28.ii.1928, and 1 ♀ on carnation flowers, Urrbrae, 19.ix.1928. Franklin's description of *insularis* applies very closely to all the specimens, though the chaetotaxy of the fore wing of the ♀ consists of fewer hairs (costa 21-25, 1st vein 15-18, 2nd vein 11-14 hairs) than stated by Franklin, and the comb of the eighth urotergum of the ♀ is usually undeveloped or consists of a small, variable number of teeth. However, I consider that these differences might easily be due to a geographical variation of the species, and the specimens do not merit a varietal name based on these characters.

Scolothrips sexmaculatus (Pergande).

One ♀, 4 ♂♂, 2 II on bean leaves, 28.ii.1928, Glen Osmond.

Physothrips kellyanus, Bagn.

Three ♀♀, 2 ♂♂ on arum lily flowers, Urrbrae, 17.ix.1928.

Physothrips simplex, sp. n.

Holotype ♀; General body-colour concolorous dark brown with a reddish tinge. The colour is due to the greyish brown cuticle covering a reddish subcuticular colour. All antennal segments dark brown except III, which is paler yellowish brown with its dorsal surface slightly darker than the ventral, and IV and V each with a pale ring near extreme base. Ocelli with dark reddish brown crescents. Mouth-cone and ends of tarsi tipped with dark brown. Maxillary and labial palpi pale brown. Legs dark brown except for yellowish brown colouring of the ventral surface and apex of fore tibia and apices and middle of other tibiae, and all tarsi are paler yellowish brown. Fore wing brown except for a pale area within the basal quarter. Hind wing very pale brown with a darker longitudinal vein. Ovipositor and all hairs brown. Much of the thicker cuticle is marked with delicate, confluent dark striae.

Measurements in μ : Length (width): Antennal segments I 29 (32), II 43 (29), III 58 (24), IV 52 (23), V 43 (21), VI 66 (20), VII 9 (8), VIII 15 (6); total length of antenna 330; head 132 (174); ocelli 9 (15); eye 84 (54); mouth-cone 150 (162 at base); maxillary palp segments I 20 (8), II 12 (6), III 20 (4); labial palp segments, I 2 (8), II 16 (2); prothorax 144 (180-216); pterothorax 270 (306); fore wing 900 (75 at middle); hind wing 762 (54); abdomen 900 (300); ovipositor 240 (120 near base); total length of insect 1470. Length of hairs: inter- and post-ocular 30; on posterior angles of pronotum, inner 80, outer 66; stiff hairs on fore wing, costa 32-90 (2), first vein 24-66 (2), second vein 46-75 (2); on abdominal segments II 14-50, IV 14-58, VIII 29-63, IX 120-148, X 52-130; teeth of comb on VIII 12.

Head with its dorsal surface marked with confluent transverse dark striae. Cheeks only slightly curved. Each eye projecting only slightly, with inner angle rounded and moderate-sized facets and about five short hairs. Ocellar lenses about equal in size. Anterior ocellus lying closer to each lateral ocellus than they are to one another; each lateral ocellus separated by about the length of its lens from the compound eye. The interocellar hairs lie between the anterior and the lateral ocelli; they are about equal in length to a pair of ante-ocellar and the pair of postocellar hairs which lies behind each lateral ocellus. Besides these hairs there is a row of two short and three longer hairs behind each eye.

Antennae 8-segmented, inserted in front below the vertex of the head and closely approximated. Segment I almost rectangular but wider at base; II barrel-shaped, but more constricted at base, which has a short annulus; III with a short pedestal, then an expansion equal in length but twice as wide as the pedestal and expanding rather abruptly into the body of the segment, which is almost parallel-sided and about 4:3 as long as pedestal and expansion before it constricts for the remaining fifth of its entire length. This segment has a strong dorsal and a slight ventral curvature outwards. Segment IV fusiform with a broad apex and a more constricted base; it has a slight dorsal and a strong ventral curvature outwards; V shaped like II but much narrower and with a slight ventral bulge; VI elongate-ovoid with broad base and with sides tapering into those of VII and VIII, which ends with a fairly blunt apex. Segments I-II are marked with faint transverse striae, III-VI bear each 3-6 transverse rings of exceedingly delicate microtrichia. A forked, curved trichome is present on the dorsal surface of III just posterior to the apex, and another is similarly placed on the ventral surface of IV. All the segments bear a few hairs.

Pronotum with angles rounded and about 25 short hairs scattered over its surface, besides the two long hairs at each posterior angle and a row of three pairs of hairs along the posterior margin, of which the innermost pair is the longest. Meso- and meta-thorax of normal structure. Legs with numerous scattered short hairs; hind tibia with a row of seven stiff hairs along its inner ventral margin and two stronger hairs at its apex. Fore wing: costa 26-31 short, 23-24 longer, more slender hairs; 1st vein with 12-15 hairs in 3 groups of 4 hairs near the base, 3-5 just past the fork and separated by a wide interval from the 4-7 which lie in the distal 2-5 of the wing;

2nd vein with 11–14 hairs; alula 5, 1 and 2 hairs. The hairs fringing the hind wing and the posterior margin of the fore wing are normal. Abdomen of elongate-ovoid shape common in genus. The dorsal hairs of segments I–VIII are short and slender, and the lateral hairs are about three times as long. The posterior margin of VIII bears a continuous comb of about 32 teeth; IX bears 3 and X 2 pairs of extra long, strong hairs, also X is split dorsally for most of its length.

Described from 5 ♀♀ found on carnation flowers, Urrbrae, S. Australia, 19.ix.1928 (*J. G. Bald*).

The holotype and one paratype are deposited in the British Museum.

Young insects are paler than the holotype and show the subcuticular reddish colour more conspicuously, with abdominal segments IX and X darker brown than the others. Amongst the Australian *Physothrips* this species comes nearest to *spiranthidis*, Bagn., from which it may be separated by coloration and measurements. It is very similar, particularly to the *adusta* forms of the European *atratus* (Hal.), from which it may be distinguished by having antennal segments III–VI shorter, and shorter inter-ocellar, pronotal and wing hairs.

***Isoneurothrips australis*, Bagn.**

Besides the 6 ♀♀, 2 ♂♂ of this collection, I have examined 35 ♀♀ from Mr. Kelly's collection from Victoria, Australia. The ♀♀ are coloured as described by Bagnall, but they vary from quite pallid (probably young) insects to much darker specimens in which a grey-brown colour is distinct on many parts of the body and is almost as dark on abdominal terga I–VIII as on segments IX–X; the fore wing also is uniform grey-brown and urotergum VIII bears on either side of its posterior margin a comb of about 8 delicate teeth $8\ \mu$ long. I proceed to describe the hitherto unknown ♂ of this species.

Male: General body-colour lemon-yellow with a brownish tinge. The concolorous abdomen is paler than the concolorous head and entire thorax. Antennal segment I pale lemon-yellow, II greyish yellow, III–V yellow with a brownish tinge which is more marked towards the apices, VI yellow with a brownish tinge more marked towards the apex of its proximal half, and its distal half and VII are greyish yellow spotted with lighter areas, the bases of (sensory?) hairs. Eyes reddish black. Ocelli with yellowish red crescents. Mouth-cone and ends of tarsi tipped with dark brown. Legs coloured like body and darkest along their outer surfaces. Fore wings pale greyish yellow with yellow veins. Hind wing very pale greyish yellow with a slightly darker longitudinal vein. Genitalia yellow; vesiculae seminales brownish yellow. The hairs, including those fringing the wings, are dark yellowish brown and their thickness is correlated with their darkness of colour.

Measurements in μ : Length (width): Antennal segment I 20 (30), II 28 (23), III 66 (17), IV 58 (17), V 37 (17), VI 63 (20), VII 11 (8); total length of antenna 295; head 100 (150); ocelli 9 (14); eyes 63 (40); mouth-cone 110 (130 at base); maxillary palp segments I 14 (9), II 12 (7), III 14 (4); labial palp segments impossible to measure in the two specimens; prothorax 145 (180–188); pterothorax 215 (260); fore wing 768 (60 at middle); hind wing 690 (44); abdomen 630 (198); penis 116 (52 near base); region of delicate chitin on urosternum III 9 (58), V 12 (46), VII 15 (46); total length of insect 1110. Length of hairs: interocular 18, postocular 20; pronotal, anterior angle 20, at posterior angle, inner 50, outer 46; on abdominal segment II 30, IV 30–35, VIII 35–43, IX inner 37, outer 46 of row of 4 hairs, midlateral 72, posterolateral 87, X 28.

Morphology like that of female. Fore wing costa with 33–35 short, 26 longer, more slender hairs; first vein 4+5–6+13–17 hairs; second vein 18–20, alula 5+2 hairs. Abdominal chaetotaxy like that of female, except that VIII bears no comb; IX bears a transverse row of 4 hairs near its posterior margin and close to the middle

line; anterior and lateral to these on either side is a stiff, shorter hair, directly lateral to them is a stiff, longer hair, and at the dorsal extremity of IX lies a pair of long stiff hairs and ventral to these a pair of little shorter hairs. Besides these IX bears 3 pairs of shorter stiff hairs and 3 pairs of very delicate, colourless hairs; X bears a dorsal pair of short stiff hairs and 2 pairs of very delicate, colourless hairs. Urosterna III-VII bear each a transverse area of delicate chitin which is parallel-sided with rounded ends and which is situated more cephalad than caudad in the tergum.

Described from type and one paratype (both deposited in the British Museum) found on arum lily flowers with 6 ♀♀, Urrbrae, S. Australia, 17.ix.1928 (*J. G. Bald*).

***Thrips imaginis*, Bagn.**

Seven ♀♀ on *Echium plantagineum* flowers, Glen Osmond, 20.ix.1928. Having examined some hundreds of specimens of this species from the collection of Mr. Kelly, Victoria, Australia, I conclude that it is in the course of being differentiated into a number of subspecies, as Priesner has described for various European *Thrips*.

***Thrips tabaci*, Lind.**

Females and nymphs II on tomato, hollyhock, marrow and *Cineraria* leaves: females alone on *Echium plantagineum* and arum lily flowers.

PHLOEOTHIRIPIDAE.

***Haplothrips victoriensis*, Bagn.**

One ♀ on arum lily flowers, Urrbrae, 17.ix.1928.

THE EARLY STAGES OF *NIPONIUS ANDREWESI*, LEW.
(COL. HIST.).

By J. C. M. GARDNER, I.F.S.,
Forest Research Institute, Dehra Dun, United Provinces, India.

(PLATE I.)

The genus *Niponius* has hitherto been studied only from the standpoint of the adult characters, the larva having been unknown. These characters were considered by Fowler (Fauna of British India, Coleoptera, General Introduction 1912, p. 93) probably to be worthy of family rank; to quote Fowler "The very curious genus *Niponius* is closely related to the HISTERIDAE, to which family it was assigned by its discoverer, Mr. G. Lewis, but it also bears affinities to other families, and is in several ways abnormal; we have therefore regarded it, with some hesitation, as provisionally separate." The structure of the male genital tube was studied by Sharp & Muir (Trans. Ent. Soc. Lond., 1912, p. 512) and they remark (*l.c.* p. 513) "The four families *Histeridae*, *Synteliidae*, *Sphaeritidae* and *Niponiidae* are so closely related by the aedeagus, that they might form one family, in which the *Histeridae* would include the higher developments."

The need for the creation of a separate family for this genus being a matter of some doubt, it might be expected that larval characters would throw light on the question, and, actually, the larva of *N. andrewesi* differs in no fundamental character from those of HISTERIDAE, a fact which supports the view that *Niponius* should be regarded as a true Histerid adapted to a special mode of life, that is to prey on the early stages at least of certain SCOLYTIDAE. It is probable that the larvae of certain other Histerids with similar habits have much in common with the larva of *Niponius*, but they are at present unknown to me.

Biological Notes.

Niponius andrewesi has been reared from time to time in the insectary at Dehra Dun from *Shorea robusta* attacked by *Sphaerotrypes siwalikensis* (SCOLYTIDAE). A search of *Sphaerotrypes* galleries at Dehra Dun, in August 1929, resulted in the collection (in addition to larvae and pupae of *Sphaerotrypes* and Clerid larvae) of several *Niponius* larvae, larval skins, prepupae, pupae, and one immature adult. One larva, taken in the prepupal form, pupated on 8th August and an adult emerged on 19th August.

The long slender larva, provided with ambulatory ampullae recalling those of Cerambycid larvae, is able to travel with ease in a subcortical gallery, but when removed from its normal home, twists about helplessly and seems unable to use its small legs. The mouth-opening is extremely small and is adapted to the absorption of liquid food, or at most of minute solid particles.

The transition in body form from the slender larva to the short, rather stout beetle is of interest; the greatest changes in length are firstly, from the normal larva to the prepupal larva, and secondly the contraction of the abdomen of the beetle after emergence from the pupal skin. A similar but more exaggerated prepupal contraction is found in *Cardiophorus* (ELATERIDAE), in which the very long, almost filiform larva contracts to a very much shorter fusiform prepupa; in the latter, however, the head is not reflexed as in *Niponius*. The pupa of *Niponius* emerges through a median slit in the thorax of the larval skin, leaving the latter otherwise intact.

Full-grown Larva (Plate i).

Body form slender cylindric, slightly narrower anteriorly. Head and prothoracic sclerites testaceous; legs and certain other sclerites very pale testaceous; remainder of body white. Setae short, sparse, many of them borne on minute pale yellowish spots on dorsal, lateral and ventral sides of body. Much of the skin's surface minutely spinulose. Length about 12.5 mm.

Head-capsule strongly depressed, exerted, directed forward; subrectangular, rounded and slightly wider posteriorly; with the posterior margin, above and below, slightly emarginate; dorsal surface weakly concave on each side of the median line; setae as figured. Gular sutures paired anteriorly forming the pregula fused into a single median line posteriorly. Epicranial suture short, distinct. Frontal sutures distinct only near their junction with epicranial suture. Ocelli absent. Epistoma produced anteriorly into a broad plate bearing a small group of setae on its rounded lateral angles; this plate itself with a flattened median spatulate projection. Labrum and clypeus not evident as separate sclerites. Mandibles dorso-ventrally flattened, curved, wide basally, slender and subacute apically; the inner margin of each with a small tooth near middle and with a basal brush of setae, most of which have minute axial branches; external margin of mandible with a single sub-basal seta. Ventral mouth-parts protracted. Maxillae free on the inner margin; stipes with fused cardo, articulated with a small tooth on hypostomal margin, subcylindric, about twice as long as wide, bearing on its inner margin a row of rather long setae (with minute axial branches) and an apical group of similar setae; palpiger joint-like, bearing on its inner margin, between base and apex, the slender cylindric mala which carries, on its obliquely truncate apex, two setae of unequal length; maxillary palps with three joints of subequal length, the terminal joint more slender. Labium with mentum and submentum rudimentary; eulabium corneous, above with a small group of branched setae on each side and a pair of subapical setae, ventrally with a pair of long setae; ligula not evident; labial palps two-jointed, the second joint the longer. Antennae inserted laterally very near dorsal articulations of mandibles, slightly shorter than mandibles, three jointed; the 1st joint cylindric, about twice as long as wide; 2nd joint subequal in length to the 1st and bearing on its expanded and obliquely truncate apex two sensory cones and a minute unisetiferous papilla; 3rd joint cylindric, with several minute sensillae on its blunt apex.

Prothorax transverse, narrower than mesothorax and somewhat depressed; tergal plate shining testaceous, with a median impressed line, posteriorly narrower and weakly bilobed; ventral surface with six testaceous sclerites as figured. Mesothorax and metathorax each, dorsally and ventrally, with a very pale testaceous shining plate, the dorsal plates transverse and with a median line; the ventral surface has, in addition, a small yellowish spot near each coxa. Legs weak, short, the distance between the coxae of each pair increasing posteriorly; five-jointed, the terminal joint styliform.

Abdomen with segments 1 to 8 each divided dorsally by transverse sulci into three zones. The anterior zone (prescutum+scutum) with a postapical, bilobed spinulose ampulla, which on tergites 2 to 8 separates two pairs of small yellowish spots; the tergite of the first segment differs in having a pair of brown corneous teeth on the ampulla and a posterior median yellowish plate; the two posterior zones (scutellum and postscutellum) shorter, the latter with a median yellowish spot. The ventral surface of these segments is also divided into three zones (presternum+sternum, sternellum and poststernellum), the anterior zone of each with a weak bilobed ampulla. The pleural zone in each segment moderately protuberant and with some small yellowish setiferous spots. The ninth abdominal segment bears on its rounded apex a pair of small two-jointed cerci, which are slightly less than one-third as long as a mandible; basal joint soft, fleshy; second joint stout, cylindric, pale yellowish, with

three or four moderately long setae on the blunt apex. Tenth segment forming a short, subcylindric pygopod.

Spiracles biforous.

Prepupal Form (Plate i, fig. 3).

The body strongly contracted, comparatively stout, cylindric; head and thorax reflexed towards the ventral abdominal surface. Length, 6 mm.

Pupa (Fig. 1).

Length, 5.5 mm. White. General form of head (including cephalic projections) and prothorax as in the adult beetle. Head above and pronotum with a few erect or sub-erect brownish setae, those on pronotum mostly in two irregular transverse rows, one subapical and one sub-basal. Abdomen distinctly longer than in adult; surface



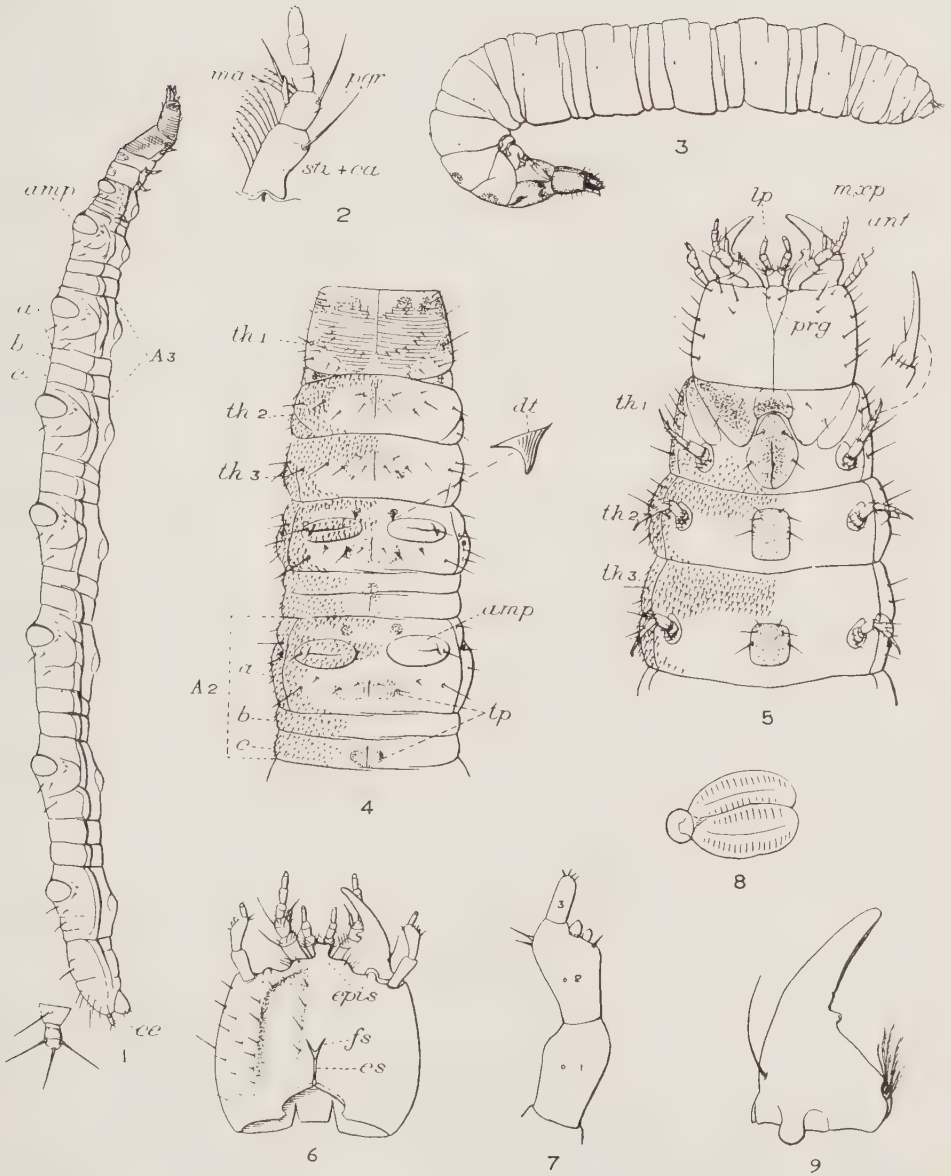
Fig. 1. Pupa of *Niponius andrewesi*, Lew., dorsal view.

minutely granulate; typical tergites each with a marginal seta on each side; the first three or four tergites each with a pair of submedian setae; the abdomen terminates in two widely separate cerci, which are divergent, slightly sinuate, soft and thicker basally and very slender apically.

EXPLANATION OF PLATE I.

Larva of *Niponius andrewesi*, Lew.

- Fig. 1. Lateral view of larva with one of the cerci (*cc*) enlarged: *A3*, 3rd abdominal segment with subdivisions *a*, *b*, and *c*; *amp*, ampulla.
2. Left maxilla, ventral view; *ma*, mala; *pgr*, palpiger; *sti+ca*, stipes and fused cardo.
 3. Prepupa, lateral view.
 4. Dorsal view of thorax and first two abdominal segments: *A2*, second abdominal segment with subdivisions *a* (prescutum with scutum), *b*, (scutellum), *c* (postscutellum); *amp*, ampulla; *dt*, dorsal tooth on first abdominal tergite, *tp*, testaceous plates.
 5. Ventral view of head and thorax: *ant*, antenna; *lp*, labial palp; *mxp*, maxillary palp; *prg*, pregula; *th 1*, *th 2*, *th 3*, thoracic segments.
 6. Dorsal view of head: *cs*, epicranial suture; *cpis*, epistoma; *fs*, frontal suture.
 7. • Antenna.
 8. Spiracle.
 9. Right mandible, ventral view.



Larva of *Niponius andrewesi*, Lew.

A NEW GENUS AND TWO NEW SPECIES OF COCCIDAE FROM THE SOLOMON ISLANDS.

By F. LAING, M.A., B.Sc.

The material upon which the following descriptions are based, was received through the Imperial Bureau of Entomology, and I am indebted to the Director of that institution for the privilege of studying it.

Neosimmondsia, gen. n.

Belonging to the group of which *Pseudococcus* may be regarded as the centre ; antennae consisting normally of 6 segments, occasionally 7 ; rostrum stout, short, dimerous ; spiracles well developed, with large opening, unaccompanied by any disc pores ; dorsal ostioles conspicuous narrow slits bounded by hard chitinous rims ; cerarii absent ; no paranal lobes ; body, on dorsum, crowded with small triangular pores ; circular disc pores present on ventral surface.

Genotype : *Neosimmondsia hirsuta*, sp. n.

I would assign this genus to a position near to *Farinococcus*, Morr., but the complete absence of anything in the nature of cerarii should serve to separate the two.

Neosimmondsia hirsuta, sp. n. (fig. 1).

Adult ♀. Material preserved in spirit, and colour not noted though a pinkish hue still noticeable in some of the specimens ; dorsum showing segmental sutures well ;

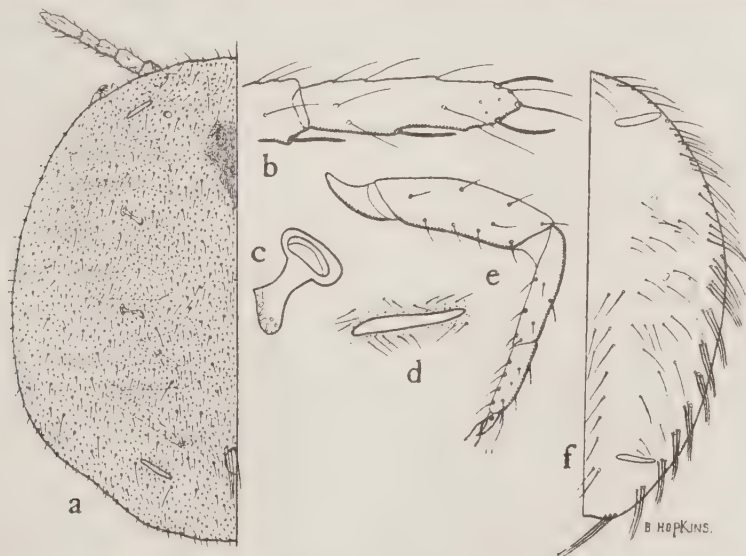


Fig. 1. *Neosimmondsia hirsuta*, sp. n., adult ♀ : a, half of dorsal surface ; b, last antennal segment ; c, posterior spiracle ; d, posterior dorsal ostiole ; e, hind leg. Half of dorsal surface of larva shown at f.

two submedian longitudinal stripes which appear to be double, the point of contact of the transverse sutures and the stripes deeply indented and dark ; a sublateral stripe may also be present ; on ventral surface the black lips of the transversely narrow ostiole conspicuous ; dorsum highly domed, venter flat, the whole outline of adult, viewed laterally, semicircular. Length 3 mm. ; breadth 2.5 mm.

Female clearing completely in potash. Antennae of 6 segments, proportions of each as follows : (1) 30 ; (2) 30 ; (3) 35 ; (4) 20 ; (5) 22 ; (6) 50 ; a few setae on each segment, a stout, blunt-pointed one at apex of V, one lateral at middle and three at apex of VI ; in one specimen examined one antenna with 7 segments due to the sub-division of III. Rostrum stout short, broad, the length a little greater than breadth, 2-segmented, the basal segment the narrower, its length a little greater than half the breadth ; the apex rather blunt. Both pairs of spiracles well developed with wide mouths and deep rims, the base of the stem glomerulate ; no accessory pores. All pairs of legs normal, robust, the hind coxae studded with minute pores on the external side ; tarsus of each pair approximately equal to two-thirds of corresponding tibia ; tarsus and tibia together slightly less than combined length of femur and trochanter ; claw without denticle ; both pairs of digitules present, surpassing apex of claw, tarsal pair filiform, knobbed, ungual pair widely expanded apically. Dorsal ostioles long narrow slits, the length quite six times the breadth, bounded by a stiff chitinous rim. Dorsum fairly thickly covered with small triangular pores and numerous longish trichiform setae, the latter more numerous on margin, but at no point forming a marginal fringe ; ventral surface with scattered circular disc pores, most numerous posteriorly, but extending right forward ; setae of anal ring of about the same strength as the marginal ; no trace of a paranal prominence. Length (under pressure) 3.3 mm. ; breadth 2.5 mm.

The pre-adult stages resemble the adult very closely except in size, the dorsum if anything somewhat more spinose, the venter lacks the circular disc pores, and there is a ventral chitinous bar on the anal segment.

The larva (embryonic) has the two pairs of dorsal ostioles similar to those of adult but, the rims are not quite so sharply defined, the triangular pores are numerous on dorsum, as well as the long trichiform setae which are arranged in a fairly definite way, and consist of a median double (quadruple in front) row, a bare space, followed by a lateral area containing roughly four irregular rows ; margin with a definite localised group of stouter setae on each segment, the posterior 7-8 segments with 3 setae in each cluster, the anterior segments with probably the same number, but the groups tend to become confluent and a fringe formed.

MALAYTA : on coconut (*H. W. Simmonds*).

***Heterococcus painei*, sp. n. (fig. 2).**

Material preserved in spirit, and secretion, if any, unknown. Adult ♀ broadly oval, deeply incised at posterior end, very hairy, not very thick from above downwards, both dorsal and ventral surfaces somewhat flat, whitish grey (when dried of spirit), dorsal surface darker than ventral, segmentation very distinct, though there is a broad dark deposition along each segment, legs and antennae slightly paler than the general ventral surface. Length 3 mm. ; breadth 2 mm.

Adult ♀ clearing, but with no special reaction, in caustic potash ; very broadly oval, when mounted, slightly incised posteriorly. Antennae 9-segmented, segments with several rather stiff, bristle-like setae, and with proportions as follows : (1) 25 ; (2) 40 ; (3) 32 ; (4) 25 ; (5) 25 ; (6) 27 ; (7) 25 ; (8) 22 ; (9) 30 ; segment 8 with a stoutish, blunt seta at apex, 9 with one on either side, but more slender than that on 8 ; ocellus distinct adjoining antennal base ; rostrum 1-segmented, considerably broader than long ; no dorsal ostioles ; median ventral cicatrice transversely broad, quite three times as wide as deep ; mouths of posterior pair of spiracles, if anything, a little larger than anterior ; legs normal, the tibia of each subequal to corresponding femur, and approximately 2.5 times the tarsus ; tarsus with a distinct tooth ; tarsal digitules exceedingly filiform, ungual pair stout, extending well beyond claw, expanded

apically; integument with many rather stout, bristle-like setae, interspersed amongst which are smaller and more slender ones; no trace of definite cerarii, but on the margins of the last three segments the general bristle-like body setae are clustered rather more numerously; anal ring distinctly longer than broad, lying apparently

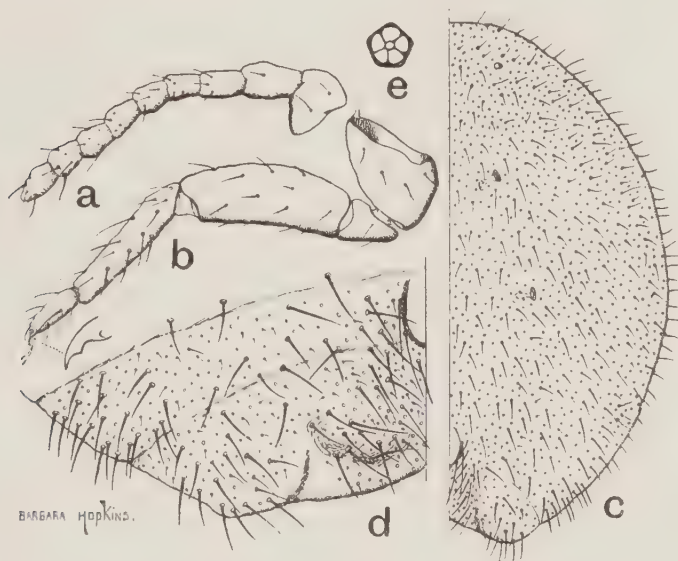


Fig. 2. *Heterococcus painei*, sp. n., adult ♀: a, antenna; b, hind leg; c, half of dorsal surface; d, hind segments enlarged; e, quinquelocular pore.

dorsally; the long auxiliary seta, usually present at least on anal lobe, apparently absent; circular quinquelocular pores present, but not abundant; ventral disc pores forming an irregular double series on the last three segments. Length 2.76 mm.; breadth 2.3 mm.

SOLOMON ISLANDS; on Coconut, viii.1928 (R. H. Paine).

The only other species assigned to *Heterococcus* are the genotype, *H. arenae*, Ferris, which has more or less well-defined cerarii on the last two abdominal segments, and *Phenacoccus nudus*, Green, which has recently been transferred to this genus, but this has the clothing of the integument totally different. Cockerell states that his *Trionymus malaitensis* runs to the genus *Heterococcus* in the table given by Ferris; as this statement might quite easily be misinterpreted, it may be said definitely that the type (which is deposited in the British Museum) shows no trace of the quinquelocular pores, so characteristic of the genus *Heterococcus*, and that it appears to be correctly placed in *Trionymus*.

A REVISION OF THE INDO-AUSTRALIAN SPECIES OF THE GENUS *MICROPLITIS* (HYM. BRACON.).

By D. S. WILKINSON,

Senior Assistant, Imperial Bureau of Entomology.

In the Transactions of the Entomological Society of London, 1929, in the introduction to my revision of the Indo-Australian and Ethiopian species of *Microgaster*, I stated my intention of writing subsequently for the related genus *Microplitis* a revision of the species from the same area. This I have done in the present paper, the slight alteration of title being necessary as no species of *Microplitis* have yet been described from the Ethiopian region.

I am much indebted to the authorities of the Hope Department, Oxford Museum, and of the National Hungarian Museum, Budapest, for permitting to be sent to me various types for examination, and also to Mr. Ramakrishna Aiyar for lending me the type series of his *ophiusae*.

Key to the Species.

1. Mesonotum red or red testaceous 2.
- Mesonotum black 5.
2. Hind tibiae with broad white annulus 1. *perlegans*, Bingh.
- Hind tibiae entirely black 3.
3. Disc of scutellum strongly margined (except at apex) 2. *radicalis*, Wilkn.
- Disc of scutellum not margined 4.
4. Wings decidedly more strongly infumated beyond than before basal vein; hind tibiae entirely, hind femora for the greater part, all tergites (except the 1st), black 3. *basalis*, Bingh.
- Wings evenly infumated throughout; hind tibiae (except at apex), hind femora and all tergites entirely, red testaceous [*chacoensis*, Cam.]
5. Propodeon with basal third horizontal and at right angles with the apical two-thirds, which are perpendicular, the point of junction sharp, not rounded; the apical two-thirds excavate; the notauli very and unusually strong, the mid-lobe of the mesonotum raised 4. *bimaculatus*, Cam.
- Propodeon not thus describable, rounded, or at least not combining the above characters (but cp. *fumipennis*, Ratz.) 6.
6. Hind femora red or red testaceous 7.
- Hind femora black, or at least darkened 11.
7. Hind coxae red testaceous 5. *pallidipes*, Szép.
- Hind coxae black 8.
8. First tergite attenuated, decidedly narrower at apex than at base [*medianus*, Rüthe]
- First tergite broader, or as broad, at apex as at base, at least not attenuated 9.
9. Second tergite smooth and shining 6. *spectabilis*, Hal.
- Second tergite more or less roughened, at least at the base 10.
10. Tegulae red testaceous [*fumipennis*, Ratz.]
- Tegulae black [*xanthopus*, Rüthe]

- | | | | | | | | |
|-----|--|-----|-----|-----|-----|-----|-----------------------------|
| 11. | Hind tibiae black with a white basal annulus | ... | ... | ... | ... | 7. | <i>manilae</i> , Ashm. |
| | Hind tibiae in basal two-thirds brownish-yellow, in apical third black | ... | ... | ... | ... | 8. | <i>atamiensis</i> , Ashm. |
| | Hind tibiae unicolorous | ... | ... | ... | ... | ... | 12. |
| 12. | Stigma with a pale cloud at base | ... | ... | ... | ... | 6. | <i>spectabilis</i> , Hal. |
| | Stigma without pale cloud at base | ... | ... | ... | ... | ... | 13. |
| 13. | Median length of 1st tergite at least two and a half times the greatest breadth of its apical fourth | ... | ... | ... | ... | 9. | <i>maculipennis</i> , Szép. |
| | First tergite not so describable | ... | ... | ... | ... | 10. | <i>similis</i> , Lyle |

1. *Microplitis perelegans*, Bingham.

Microgaster perelegans, Bingham, Trans. Ent. Soc. London, 1906, p. 126; Dodd, Trans. Ent. Soc. London, 1906, pp. 120, 121.

Microplitis perelegans, Bingham, Wilkinson, Trans. Ent. Soc. London, 1929, p. 122.

A species described from two females and two males.

Type in the Oxford Museum; cotypes in the British Museum.

The type locality is Townsville, North Queensland.

Host. Mr. Dodd records the host as the larva of a Notodontid moth, *Notodonta cynoptera*, Lower; this genus is known in the British Museum, at the moment, under the name *Furcula*.

M. perelegans is also known to me through three females(?) in the British Museum presented by Mr. R. E. Turner and labelled Townsville, Queensland, 27.ii.1902, 5.iii.1902, 3.i.1903 (*F. P. Dodd*).

2. *Microplitis radicalis*, Wilkn.

Microplitis radicalis, Wilkinson, Bull. Ent. Res., xx, 1929, p. 206.

A species described from 4 ♀♀, 6 ♂♂.

Type in the Zoological Museum, Berlin; cotypes in the British Museum.

The type locality is China.

Host unknown, possibly the larva of a Sphingid moth.

3. *Microplitis basalis*, Bingham.

Microgaster basalis, Bingham, Trans. Ent. Soc. London, 1906, p. 125; Dodd, Trans. Ent. Soc. London, 1906, pp. 120, 122.

Microplitis basalis, Bingham, Wilkinson, Trans. Ent. Soc. London, 1929, p. 122.

A species described from apparently two males.

Type in the Oxford Museum.

The type locality is Townsville, North Queensland.

Host. Mr. Dodd records the host of the type as the larva of a Sphingid moth, *Theretra oldenlandiae firmata*, Walker, and the host of the cotype as the Sphingid, *Cephonodes kingi*, McLeay.

This species is known to me from the type only.

4. *Microplitis bimaculatus*, Cam.

Microplitis bimaculatus, Cameron, Soc. Ent., xxiv, 1909, p. 133.

A species apparently described from a single male.

Type in the British Museum.

The type locality is Kuching, Borneo.

Host unknown.

This species is known to me from a male and a female, both labelled as type, in the British Museum; and from a female in the Zoological Museum, Berlin, labelled, Neu-Guinea, Milne Bay, Micholitz S., R. Krieger V.

5. *Microplitis pallidipes*, Szépligeti.

Microplitis pallidipes, Szépligeti, Termes. Fuz., xxv, 1902, p. 64.

♂. Black; scape, tegulae, legs (including coxae), abdomen in at least basal half, red testaceous; flagellum dark brown; stigma (with a pale cloud at base) and wing veins brown, except the costa which is rather darker; wings definitely infumated.

♂. Agrees closely in sculpture with *M. medianus* (even in venational characters), except in the 1st tergite which is parallel-sided throughout save at the apical fourth where the sides roundly converge to the more or less truncate or possibly even slightly emarginate apex, the apical fourth of the tergite being turned over and down and the basal half somewhat excavated.

Length, 1.5 mm.

Redescribed from a single specimen, a male, labelled "*pallidipes* det. Szépligeti," which I have reason to believe is the unique type.

Type in the National Hungarian Museum.

The type locality is Singapore.

Host unknown.

6. *Microplitis spectabilis*, Hal.

Microplitis spectabilis, Haliday, Ent. Mag., ii, 1834, p. 236.

Dapsilotoma testaceipes, Cameron, J. Bombay Nat. Hist. Soc., xvii, 1906, p. 101 (*syn. nov.*).

This comparatively common European species is known to me in the region with which we are dealing from two males described by Cameron, as females, under the name *testaceipes*. The genus *Dapsilotoma* was erected for these individuals, Cameron having apparently miscounted the antennal joints, which are of the normal number.

Type of *D. testaceipes* in the British Museum.

The type locality of *D. testaceipes* is Quetta, India.

7. *Microplitis manilae*, Ashm.

Microplitis manilae, Ashmead, J.N.Y. Ent. Soc., xii, 1904, p. 20.

A species described from one male and one female.

Type in the United States National Museum.

The type locality is Manila.

Host unknown.

I have not seen this species, but have succeeded in including it in my key.

8. *Microplitis atamiensis*, Ashm.

Microplitis atamiensis, Ashmead, Proc. U.S. Nat. Mus., xxx, 1906, p. 194.

A species described from a single male.

Type in the United States National Museum.

The type locality is Atami, Japan.

Host unknown.

I have not seen this species, but have succeeded in including it in my key.

9. *Microplitis maculipennis*, Szép.

Microplitis maculipennis, Szépligeti, Termes. Fuz., xxiii, 1900, p. 60.

Microplitis eusirus, Lyle, Bull. Ent. Res., xii, 1921, p. 129 (*syn. nov.*).

Microplitis ophiussae, Ramakrishna Aiyar, J. Bombay Nat. Hist. Soc., xxviii (1), 1921, p. 298 (*syn. nov.*).

Szépligeti described his species from a single female; Lyle, from one male, two females, and fragments of two others; Ramakrishna Aiyar, from apparently a series of four.

Type in the National Hungarian Museum; Lyle's series in the British Museum.

The type locality is Friedrich-Wilhelmshafen, New Guinea; Lyle's series was taken at Pusa, Bihar & Orissa, India, and Ramakrishna Aiyar's in Coimbatore, South India.

Host. Szépligeti gives no host; both the Indian series were bred from the Noctuid moth, *Achaea janata*, (L.=*melicerte*, Hamps.).

This species is known to me both from Szépligeti's unique specimen and from the two Indian series.

10. *Microplitis similis*, Lyle.

Microplitis similis, Lyle, Bull. Ent. Res., xii, 1921, p. 129.

A species described from six females and four males.

Type in the British Museum.

The type locality is Pusa, Bihar & Orissa, India.

Host. The Noctuid moth, *Agrotis ypsilon*, Hufn.

Additional Species.

Microplitis philippinensis, Ashm.

Microplitis philippinensis, Ashmead, J.N.Y. Ent. Soc., xii, 1904, p. 20.

A species described from two males.

Type in the United States National Museum.

The type locality is Manila.

Host unknown.

This species is not known to me. From the description it would appear to run to couplet 11 of my key, beyond which, however, I cannot take it since I cannot determine from the description the colour of the hind tibiae.

Microplitis sapporoensis, Ashm.

Microplitis sapporoensis, Ashmead, Proc. U.S. Nat. Mus., xxx, 1906, p. 194.

A species described from a single female.

Type in the United States National Museum.

The type locality is Sapporo, Japan.

Host unknown.

This species is not known to me. From the description it would appear to run to couplet 6 in my key, beyond which, however, I cannot take it as from the description I cannot determine the colour of the legs.

					Host List.
<i>Achaea janata</i> , L.	...	...	...	...	<i>M. maculipennis</i> , Szép.
<i>Agrotis ypsilon</i> , Hufn.	...	...	...	...	<i>M. similis</i> , Lyle
<i>Cephonodes kingi</i> , McLeay	...	...	...	...	<i>M. basalis</i> , Bingh.
<i>Furcula</i> ; see <i>Notodonta</i> .					
<i>Notodonta cynoptera</i> , Lower	...	...	...	...	<i>M. perelegans</i> , Bingh.
<i>Theretra oldenlandiae firmata</i> , Walk.	...	...	...	...	<i>M. basalis</i> , Bingh.

Species of Microplitis mentioned in this paper.

<i>atamiensis</i> , Ashm.	...	...	25	<i>pallidipes</i> , Szép.	...	...	25
<i>basalis</i> , Bingh.	...	...	24	<i>perelegans</i> , Bingh.	...	...	24
<i>bimaculatus</i> , Cam.	...	...	24	<i>philippinensis</i> , Ashm.	...	...	26
<i>chacoensis</i> , Cam.	...	...	23	<i>radicalis</i> , Wilkn.	...	...	24
<i>eusirus</i> , Lyle	...	...	26	<i>sapporoensis</i> , Ashm.	...	...	26
<i>fumipennis</i> , Ratz.	...	...	23	<i>similis</i> , Lyle	...	...	26
<i>maculipennis</i> , Szép.	...	...	26	<i>spectabilis</i> , Hal.	...	...	25
<i>manilae</i> , Ashm.	...	...	25	<i>testaceipes</i> , Cam. (<i>Dapsilotoma</i>)	...	...	25
<i>medianus</i> , Ruthe	...	...	23	<i>xanthopus</i> , Ruthe	...	...	23
<i>ophiusae</i> , R. Aiyar	...	...	26				

A NOTE ON *STIBAROPUS TABULATUS*, SCHIÖ. (HEM., PENT.), A NEW PEST OF TOBACCO IN SOUTH INDIA.

By P. N. KRISHNA AYYAR, B.A.,
Madras Agricultural Department.

Stibaropus tabulatus, Schiödte, a Pentatomid bug of the subfamily CYDNINAE, is remarkable in having the unusual habit of living underground and attacking the roots of tobacco, and to the best of the writer's knowledge this is the first record of this species as an insect of economic importance; though Lefroy has mentioned the allied *S. molginus*, Schiödte, in his "Indian Insect Life" (p. 674) as having been observed at the roots of a palm in South India at a considerable depth below the surface. As the insect under report was something of a novelty and was a pest of such a valuable crop like tobacco, the writer made special efforts to study its life-history and habits, and it is the aim of this paper to place on record the results of his observations and studies, though he regrets that they are somewhat fragmentary in character.

In December 1925, in response to a report received by the Government Entomologist concerning damage caused by certain underground insects to the tobacco crop at Satyamangalam, 42 miles from Coimbatore Town, the writer was deputed to examine and report on the pest.

Though there is an extensive area under tobacco in the tract round Satyamangalam, the pest in question was, curiously, confined to a single garden in this locality comprising an extent of about 10 acres. This garden is situated on the left bank of the Bhavani River and is well isolated from the rest of the area by means of certain natural, as well as artificial barriers. This particular spot differed in some essential respects from the rest of the garden. The loose loamy soil of the garden had had its fertility greatly augmented by the deposition of a fine stratum of alluvial silt conveyed during the unprecedented floods of the previous year. The character of the soil had further been altered to a certain extent owing to the peculiarities of cultural methods practised and to the application of soil from other places. The cumulative effect of all these had rendered the texture of the soil ideal for subterranean insects to thrive at their best, because their requirement, among other things, of a plentiful supply of air is amply met.

The symptoms of damage by this insect were not sufficiently distinctive. To a casual observer the affected plants presented a sickly appearance in general. There was a gradual withering of the leaves, which at first turned yellow and then brown. The plants were considerably weakened and became stunted in growth. A slow dying of the stem ensued, resulting in the ultimate succumbing of the plant. In areas badly affected small patches of plants already dead and dying were distinctly observed.

On uprooting a plant by gradually loosening the soil around and taking care to keep the roots intact, as many as 20 to 30 bugs were noted attached to the roots and rootlets, and the writer was specially struck with their close resemblance to certain Melolonthid beetles in colour, form, and size. On beginning to loosen the soil around the plant the presence of these bugs was indicated by the characteristic nauseous smell that emerged. These bugs were also to be found in the interspaces between plants. Though the number found attached to the roots and rootlets may be as high as 30, it averaged between 10 and 20, and the bugs were found at depths varying from one to six inches. A careful examination of the roots at the time of digging up the plant showed that they actually attack the roots, since bugs were found with their beaks thrust into the tissues; but this is usually rather difficult to observe, as the

insects show a tendency, the moment they are exposed, to loosen their hold and to drop down and remain motionless, feigning death. If such specimens are again placed on loose soil they resume their activity and work their way into the soil, making a little neat oval space for themselves to live in, using for this purpose chiefly their legs, especially the hindmost pair, which are peculiarly modified for digging purposes. The hind legs are disproportionately stout, though short, and have their tibiae greatly enlarged and abruptly truncated at the tip, forming a large oval disc encircled by closely set spines.

On a thorough inspection of the gardens within a radius of nearly 3 to 4 miles, it was observed that the pest was to be found attacking tobacco plants only in this garden and that all surrounding tobacco gardens in the locality were free from it. The reason, however, for this localised appearance is not quite evident. Perhaps to some extent it may be due to the loose texture of the loamy soil of this garden.

Several plants and weeds growing within the garden and round about were dug up and found to be free from attack. No bugs were observed at the roots of palms, plantains, grasses, chillies, brinjals, etc. The soil in the interspaces between the plants only occasionally showed one or two stray bugs. The bunds and other places where there were no tobacco plants yielded no bugs. Plants in the same garden that looked healthy and had their normal growth generally harboured none or only one or two, whereas tobacco plants which were stunted, and in other ways had the characteristic symptoms, had a large number attached to their roots, and such plants were found to be free from any other insect pests or fungous diseases. All this clearly goes to prove that the bug has a peculiar affinity for the tobacco plant alone and is the sole cause of this affection; it is certainly capable of causing immense injury to this crop. The old and experienced ryots of the locality could not add anything more to what was observed, since they had not previously seen this pest either here or elsewhere.

Investigations as to the probable source of infestation proved futile. The nursery was subjected to careful examination. The soil from prickly pear areas, which was applied as manure to the tobacco, was examined, as also the manure pit and other possible sources, but all to no purpose.

As already noted, the bug is a small, oval, deep brown insect with a strong resemblance to a chafer beetle. The bugs burrow into and excavate passages near the roots below the surface of the soil; at intervals, these passages are sometimes found to be slightly enlarged into small oval chambers, and in the chamber near the roots the male and the female are occasionally found pairing. The sexes are not easily distinguishable, but males are generally smaller.

The life-history of the pest was only partly worked out. Numerous attempts to rear them proved unsuccessful, as it was found difficult to produce the natural conditions owing to the unusual habits of the nymphs and adults. The eggs are deposited near the roots or rootlets of tobacco plants, but the exact number laid by one female could not be determined. A few females were dissected, and the mature, or nearly mature, ova were found to be only 3 to 5 in each individual. Little value, however, could be attached to this, as it is quite probable that the bugs would continue to lay a few eggs at a time for considerable periods. In the field eggs were found laid at depths varying from 3 to 6 inches. They are laid singly in the soil with apparently no selection of place. In captivity, in spite of numerous attempts, oviposition was actually seen only in a few cases. In the case of a pair taken in copulation on 15th December 1926, two eggs were found laid on 6th January 1927. Another pair was taken on 12th January, and one egg was laid on 18th and another on 29th January. Generally speaking, the eggs are laid one at a time, and rarely two. The eggs are peculiar in that they are not of the usual Pentatomid type. They are cylindrical with smooth rounded ends, and their length varies from 1.7 mm. to 1.8 mm. with a

width of 0.8 mm.-0.9 mm. The egg period lasts from 4 to 15 days, averaging 7 days for 5 individuals. The newly hatched nymph is whitish in colour with a shade of brown on the head, 2.0 mm.-2.1 mm. in length, and 1.0-1.1 mm. in breadth. Rostrum slender and four-jointed, reaching beyond hind coxae. Head and prothoracic shields brownish white. Antennae whitish, with 4 distinct joints, the last joint much bigger than the others and nearly 1.0 mm. long; the other joints present a beaded appearance. First pair of legs smaller than the rest, with thin femora, tarsi spinose and sickle-shaped; second pair thinner than the first, with long femora, tarsi spinose; third pair of femora stout, tibia cylindrical and truncate.

Recently hatched nymphs, if disturbed or placed on the surface of the loose soil in which they live, commence to burrow slowly and soon disappear. Apparently they do so to avoid light, as their natural habitat is below the surface of the soil at the level where the adults are found.

Four other distinct stages were observed among the nymphs, but the exact number and length of the various stages were not accurately noted, as nymphs that were isolated with that object in view all died.

This pest, affecting as it did a whole garden of a very valuable crop of tobacco, and, presumably subsequent crops as well, presented a problem of some magnitude and several measures were tried to bring it under control. Crude oil emulsion at a strength of 1 lb. in 8 gallons of water was applied round plants (about 60 in number) by means of a rose can after loosening the soil round the plant. The treated plants were dug up the following day and 60 per cent. of the bugs were found dead and the rest, though alive, inactive. A stronger dose was deemed necessary, and therefore crude oil emulsion at a strength of 1 lb. in 6 gallons of water mixed with tobacco decoction (1 lb. soaked in 1 gallon of water kept overnight and diluted with an equal quantity of water) was applied as before round some 80 plants in another area. These were examined after about a week, and the results were distinctly promising, some plants which before were apparently dying having recommenced to grow; and on examination of the roots and soil underneath, over 95 per cent. of the bugs were found dead. One or two bugs were observed alive here and there near the plants; this might be due to the variation in the quantities of emulsion applied round the plants.

It is clear from the above, that if a sufficient quantity of crude oil emulsion of the strength 1 : 6 is applied, the pest may be completely destroyed without in the least impairing the growth of the plant.

Light traps were put up in the area, but very few insects were attracted to these.

Further attempts are being made to investigate the bionomics of this interesting and novel pest of tobacco, and the foregoing notes are published only with the idea of inviting the attention of economic entomologists in different parts of the world to this new pest of a valuable crop.

ON SOME EGG-PARASITES FROM AFRICA.

By CH. FERRIÈRE, D.Sc.,

Senior Assistant, Imperial Bureau of Entomology.

Family EUPELMIDAE.

Anastatus blattidarum, sp. n. (fig. 1, *a* & *b*).

♀. Head shining green; face and front with purplish shine. Thorax orange-yellow, with a small black spot on each side of the pronotum; mesopleurae and propodeon slightly brownish. Abdomen aeneous-black, with dark green shine near the end; first segment (except two brown spots at the sides) and second segment (except hind border) whitish. Valvae of ovipositor white. Antennae brown, with scape and pedicel yellow. Wings dark brown, with the base and a bent stripe in the middle hyaline. Legs brownish yellow, with the trochanters and tip of tibiae and tarsi clearer yellow; base of hind coxae and a stripe on the inner side of middle and hind femora dark brown.

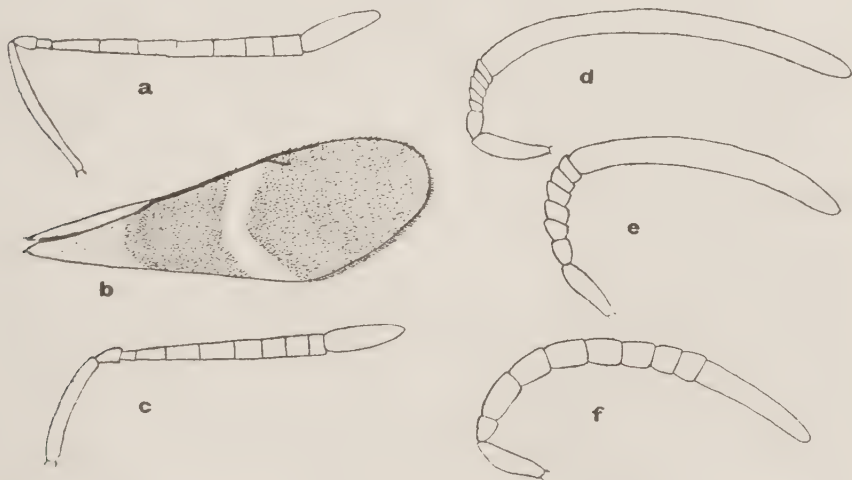


Fig. 1. *Anastatus blattidarum*, sp. n., ♀: *a*, antenna; *b*, forewing. *Anastatus bifasciatus*, Fonsc., antenna of: *c*, ♀; *d*, var. *longiclava*, n., ♂; *e*, var. *antestiae*, n., ♂; *f*, var. *hancocki*, n., ♂.

♀. Head finely shagreened, more rugulose in the antennal furrow, and with very fine longitudinal striae behind the eyes and the cheeks. Antennal furrow surrounded by a small carina. Middle ocellus situated above the antennal furrow; lateral ocelli very near the eyes. Cheeks almost as long as the eyes, with a longitudinal furrow between the eye and the mandible. Antennae inserted a little under the level of the lower margin of the eyes. Scape narrow, elongate, as long as the annellus and the three first funicle joints together; pedicel not broader than scape, more than twice as long as broad; annellus small, almost quadrate; 1st funicle joint narrower than the pedicel and almost twice as long; the following joints gradually increasing in breadth and diminishing in length, but all longer than broad, the 6th and 7th only slightly so; club with three joints, not much broader than the funicle, not quite as long as the three preceding joints together. Thorax almost entirely smooth and

shining; only the anterior part of the median lobe of the mesonotum dull and ruguloso-punctate. Scutellum and axillae very finely longitudinally striate; axillae separated from each other, on the hind margin of the mesonotum, by a length equal to the third of their breadth. Propodeon very short in the middle, the lateral margins somewhat inflated. Wings with the marginal vein as long as the submarginal; the postmarginal vein about half the length of the marginal; the stigmal vein shorter than half the length of the postmarginal. The hyaline band, under the distal third of the marginal vein, has the inner margin regularly curved and the outer margin angulated in the middle. Legs long and slender; femora and tibiae a little thickened near the tip; median tarsi with small black teeth under the metatarsus and at the end of the 2nd and 3rd joints; the other tarsi more elongate, the anterior longer than, the posterior as long as, their tibiae. Abdomen smooth, finely shagreened, as long as the thorax, narrow at the base, widening to the 5th segment, where it is as broad as the thorax, then strongly narrowed to the tip. Ovipositor only slightly protruding.

Length, 2.6 mm.

ANGLO-EGYPTIAN SUDAN: Khartoum, 2 ♀♀, 5.i.1925, 1 ♂, 3.viii.1924 (*R. Cottam*).

Host. Bred from an egg-case of a cockroach.

Another species, *A. blattidifurax*, Girault, is known to attack cockroach-eggs in Australia. It differs from the African species especially in the coloration, the body being entirely dark metallic blue, except for a white band at the base of the abdomen, and the forewings are infuscated from the bend of the submarginal vein to the tip, with only a narrow curved transverse stripe in the middle. *A. blattidarum* may be easily recognised by its green head, reddish thorax, and aeneous abdomen, and by the slender antennae and legs.

Anastatus bifasciatus, Fonsc.

Cynips bifasciata, Fonscolombe, Ann. Sc. Nat., xxvi, 1832, p. 294.

Anastatus bifasciatus (Fonsc.), Ruschka, Verh. zool.-bot. Ges. Wien, 1921, p. 264;

Bolivar y Pieltain, Rev. de Fitopatologia, 1923, p. 116.

Specimens received from East Africa agree almost exactly with the descriptions of this European species given by Ruschka and Bolivar. As it is interesting to find this species in tropical Africa, and as there are some varieties, especially among the males, some of which have, curiously enough, been bred from eggs of an Hemipteron, we think it better to give here short descriptions of each form.

♀. The same as the European type; the thorax is more greenish without violet coloration, but the vertex, scutellum, axillae and abdomen have also a bronze colour. The second segment of the abdomen is not distinctly whitish at the end, but is only slightly clearer, more or less translucent. The relative length of the antennal joints the same, except that the 2nd joint of the funicle is a little shorter, being not much more than twice as long as broad (fig. 1 c). The transverse hyaline stripe in the middle of the forewings a little narrower.

Length, 3 mm.

UGANDA: Kampala, 3 ♀♀, 1926 (*H. Hargreaves*).

Host. From eggs of a Lasiocampid moth, *Gonometa fasciata*.

♂♂. Though agreeing in size and coloration with the European type, they all differ in antennal characters. By the form of the antennae they may be separated into three varieties, as follows:—

A. bifasciatus var. *antestiae*, nov.

Antennae with the five funicle joints all transverse; 1st and 2nd about one and a half times, the 4th and 5th more than twice, as broad as long; club almost twice as long as the rest of the antenna (fig. 1 e). Hind tibiae with the extreme base white.

Length, 1.3–1.4 mm.

UGANDA: Toro, 11 ♂♂, vi.1925 (G. L. R. Hancock).

Host. From eggs of a Pentatomid, *Antestia lineaticollis*, Stål.

In the typical male of *bifasciatus* the 1st funicle joint is longer than broad, the 2nd and 3rd about quadrate, and only the 4th and 5th strongly transverse.

A. bifasciatus var. **hancocki**, nov.

Antennae with seven funicle joints; the 1st twice as long as broad, the following decreasing gradually in length, the 6th quadrate, the 7th broader than long; club distinctly longer than the four preceding joints together (fig. 1 f). Hind tibiae with the basal third white.

Length, 1.3–1.4 mm.

UGANDA: Toro, 6 ♂♂, vi.1925 (G. L. R. Hancock).

Host. From eggs of a Pentatomid, *Antestia lineaticollis*, Stål.

Bred from the same host and at the same time as var. *antestiae*, this variety belongs undoubtedly to the same species. On account of the seven funicle joints it would seem to be more closely related to *A. disparis*, Ruschka, but in that species the club is much shorter, being only as long as the three preceding joints together.

A. bifasciatus var. **longiclava**, nov.

Antennae with five funicle joints, all strongly transverse and together much shorter than the scape; the club very much elongate, more than two and a half times as long as the rest of the antenna (fig. 1 d). Legs as in var. *antestiae*.

Length, 1.6 mm.

UGANDA: Toro, 6 ♂♂, 1925 (G. L. R. Hancock).

Host unknown.

This variety, with its body less shining, the clear parts of the legs more yellowish than white, and the extraordinary form of the antennae, which are more ciliate than in the other varieties, will probably prove to be a distinct species.

Mesocomys pulchriceps, Cam.

Mesocomys pulchriceps, Cameron, Proc. S. Afr. Philos. Soc., xv, 1905, p. 210.

The genus *Mesocomys*, Cam., is related to *Anastatus*, Motsch., from which it can be readily distinguished by the two grooves at the base of the scutellum in the female, by the shorter antennae with subquadrate or transverse funicle joints, the pedicel being as long as the first three funicle joints together, and by the wings, which are entirely infuscated with only the base hyaline and two whitish rounded spots, one under the marginal vein, the other opposite near the hind margin of the wing. The wings of the male are entirely hyaline.

The only known species seems to be widely distributed throughout South Africa. Cameron gives as host the larva of a Calliphorid fly, *Chrysomya chloropyga*, but his information was probably erroneous, as all specimens found later have been bred from Lepidopterous eggs.

In the British Museum is a series determined by Dr. Waterston of ♂♂ and ♀♀ from NORTHERN NIGERIA (*H. Liddiard*), bred from eggs of a Bombycid. The following series have been received by the Imperial Bureau of Entomology:—NATAL: New Hanover, 23 ♀♀, 10 ♂♂, 1915 (*C. B. Hardenberg*); host not mentioned. ORANGE FREE STATE: Bloemfontein, 2 ♀♀, 2 ♂♂ (*H. K. Munro*); host unknown. CAPE PROVINCE: Dohne, 5 ♀♀, 31 ♂♂, xii.1921 (*H. K. Munro*); from eggs of *Gonimbrasia tyrreha*, Cramer (Saturniidae).

The morphological characters are very constant and there are only slight variations in the coloration. The specimens from Bloemfontein are more bluish purple and have the antennae entirely yellow, with only the pedicel dark.

Anastatus vuilleti, Crawford 1912, from French Sudan, Koulikoro, reared from the eggs of *Cerina butyrospermi*, Vuillet, belongs to the genus *Mesocomys*. From the description it differs somewhat in its smaller size and in the coloration but it is probably only a variety of *Mesocomys pulchriceps*, Cam.

Family EULOPHIDAE.

***Tetrastichus ovulorum*, sp. n. (fig. 2).**

♂. Body black, without metallic shine. Abdomen with a large rounded yellow spot near the base, this spot being more conspicuous in the female than in the male. Antennae brown, scape and pedicel yellow. Legs entirely clear yellow, except the anterior coxae which are partly brownish. Wing nerves very pale yellow.

♀. Head short, vertex narrow, with the ocelli disposed in a low triangle, the lateral ocelli as far from each other as from the eye-margins. Eyes short oval, the cheeks almost as long as the diameter of the eyes. Mandibles with two acute teeth

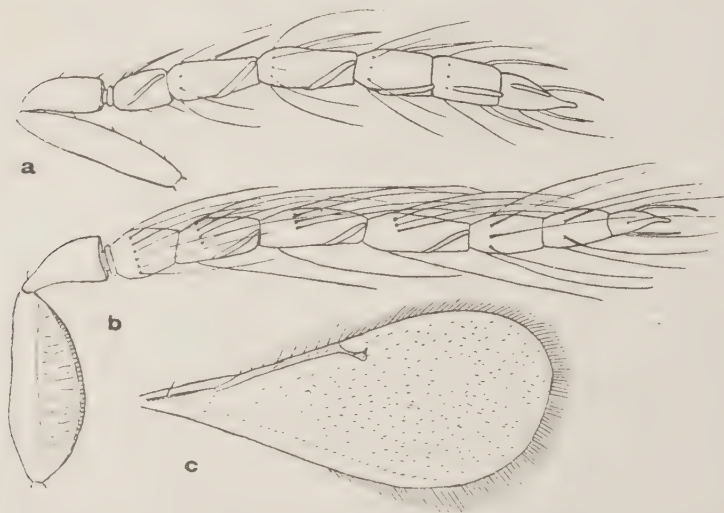


Fig. 2. *Tetrastichus ovulorum*, sp. n. : a, antenna of ♀; b, antenna of ♂; c, forewing.

of equal length, the lower margin rounded below the second tooth. Palpi rather long and slender, the maxillary palpi three times as long as the labial. Antennae inserted in the middle of the face, a little above the level of the base of the eyes. Scape narrow, reaching to the front ocellus, longer than the pedicel and the 1st funicle joint together; pedicel more than twice as long as broad; two small transverse annelli; 1st funicle joint much shorter than the pedicel, not much longer than half the next joint; 2nd joint longer than the pedicel; 3rd as long as 2nd; club almost as long as the three funicle joints together, with three elongated joints, the first two as long as the pedicel, the 3rd a little shorter, much pointed at the end. Each joint of the funicle and of the club bears at the base a few long bristles as long as the joint itself, and on the side a shorter thickened hair; each joint also with a large, obliquely placed sensillus, and sometimes with a short straight sensillus on the other side. Thorax rounded, not

much longer than broad, almost smooth and shining; with a stronger lens the mesonotum and scutellum are seen to be very finely striate. Parapsidal furrows strong; the longitudinal furrows on mesonotum and scutellum very weakly marked and not easily seen. Propodeon short, angled at the sides, with rather large, rounded spiracles. Wings large, as long as the body, and broadly rounded at tip. Submarginal vein with a single bristle on the upper side and two to four bristles directed downward; marginal vein somewhat thickened, twice as long as the submarginal; stigmal vein elongate, thin at the base, oval at the end, about as long as one-fourth the marginal vein. The discal cilia short and not very dense, forming a regular row near the lower margin of the wing; length of marginal hairs about one-sixth the width of wing. Hind wings narrow, the marginal hairs as long as the greatest width of the wing. Legs slender, almost bare, with only few very short hairs; tibiae longer than femora; the tarsal joints subequal in length, except on the anterior tarsi, where the 1st joint is shorter than the following. Abdomen short, rounded, not much longer than the thorax, the segments transverse. Ovipositor slightly protruding.

♂. Similar to the female in size and form. Antennae more elongate; scape strongly broadened below and oval, owing to the great development of the sense-organ, which covers all the lower part of the scape and is almost broader than the rest of the joint; pedicel shorter than half the scape, and twice as long as broad; annellus short, transverse; 1st funicle joint short, not much longer than broad; 2nd distinctly longer, as long as the pedicel; 3rd and 4th longer and narrower than the 2nd, subequal in length; club as long as the two preceding joints together, with three narrow and elongated joints, the 3rd pyriform and pointed at tip. Each funicle joint bears a whirl of very long bristles, which are as long as two joints together; on the club the bristles are a little shorter and not so dense; the last joint with two thick hairs reaching beyond the tip of the antenna; 2nd-4th joints each with a large obliquely placed sensillus. Abdomen narrower than in the female, with a long protruding penis.

Length, ♀♂, 0.9-1.0 mm.

SIERRA LEONE: Njala, many ♀♀ and ♂♂, 5.ix.1928 (*E. Hargreaves*).

Host. From eggs of a Coccinellid beetle, *Epilachna chrysomelina*, F.

This species is characterised by its small size, by the form of the antennae, in which the 1st funicle joint is much shorter than the 2nd joint and than the pedicel, and by the great development of the sense-organ of the male, which gives to the scape an enlarged and almost foliaceous form. Through the presence of only one bristle upon the submarginal vein, this species is a true *Tetrastichus*, Hal., according to the divisions of Kurdjumov.

This species must not be confused with *T. epilachnae*, Giard, or *T. coccinellae*, Kurdj., both parasites of Coccinellids in Europe: morphologically, the size, form of antennae and coloration are quite different, and biologically, the two European species are known to parasitise the nymphs of COCCINELLIDAE, whereas we have here a real egg-parasite.

Family TRICHOGRAMMIDAE.

Trichogramma lutea, Gir.

Trichogrammatoidea lutea, Girault, Trans. Amer. Ent. Soc., xxxvii, 1911, p. 19.

Girault established the genus *Trichogrammatoidea* for the species *Chactostricha nana*, Zehnt., from Java, a parasite of *Diatraea saccharalis*, and for this South African species, bred from eggs of *Cydia (Carpocapsa) pomonella*. The first species has been recognised by different authors to belong to the genus *Trichogramma*, Westw., and the second, of which we have received specimens from Natal, is also referable to this latter genus.

The genus *Trichogrammatoidea* is characterised by Girault in the following terms :

"A genus closely allied with and resembling *Pentarthron*, Riley, but differing from it in having slightly narrower fore wings which lack the short oblique line of discal cilia running proximo-caudad from the stigmal vein and which have longer marginal cilia, especially distad, somewhat as in *Oligosita*, Haliday, of the other subfamily, but not so long. Further than these, the male antennae are distinctly segmented, not nodular, 8-jointed, and the antennae of both sexes, in the type species at least, bear peculiar minute bladder-like appendages on the funicle joints which have not as yet been found to occur in any other genus."

Considering these characters, we find that the short oblique line of cilia under the stigmal vein may be present in larger specimens and absent in smaller ; the marginal cilia are also a little shorter in large specimens, but they are still always longer than in *T. evanescens*, Westw. ; the antennae of the male are as in *Trichogramma* with an elongate distal joint, the folds of which may be taken for divisions between different joints ; lastly, the minute bladder-like appendages, which break off very easily, may be found on the funicle joints of other species ; we have seen them on the antennae of many females of *T. evanescens*, Westw.

Trichogrammatoidea, Girault, is thus a synonym of *Trichogramma*, Westw. (*Pentarthron*, Riley) and *T. lutea*, Gir., may be characterised by its entirely yellow coloration, by the longer marginal hairs of the wings, the largest of which are about as long as a fifth of the width of the wing, and by the more scattered discal cilia on the fore wings, arranged in 12 to 15 rows of not many hairs. Length, ♀ 0.45-0.70 mm., ♂ 0.30 mm.

The specimens examined are 3 ♀♀, 1 ♂, from Magut, Natal (*F. S. Parsons*), from eggs of *Diparopsis castanea*, Hampson.

Family MYMARIDAE.

Anaphoidea gonipteri, sp. n. (fig. 3).

♂♂. Body brownish black. Antennae brown with the pedicel clearer. Legs with black coxae and femora, brown middle and hind tibiae (yellowish at the base), and yellow trochanters, anterior tibiae, and tarsi, the latter darker at tip. Wings hyaline, with a curved brownish stripe which stretches from the base of the wing to the marginal vein, where it is thinnest, and from there to the hind margin of the wing, leaving under the marginal vein a rounded hyaline spot ; this stripe continues, less visible and narrow, along the hind margin. Wing veins brown.

♀. Head transverse. Cheeks as long as the diameter of the eyes. Antennae inserted a little above the middle of the face, with 10 joints, finely ciliate. Scape broadened in the middle, but not broader, and only slightly longer, than the pedicel ; pedicel about one and a half times as long as broad ; 1st funicle joint annuliform, half as long and as broad as the pedicel ; 2nd joint much longer, more than twice as long as the pedicel ; the following joints a little shorter ; club with two joints, a little longer than the two preceding joints together. The relative length of the joints as follows : Scape 16 ; pedicel 10 ; funicle 5, 24, 22, 22, 21, 17 ; club 42. Thorax smooth, longer than broad. Wings very large, longer than the body, broadened at the end, the stigmal vein at one-third the length of the wing. Marginal vein longer than broad, continued straight by the stigmal vein, which is parallel to the wing margin. Surface of wing densely covered with small cilia from an oblique line under the marginal vein ; base of wing, and two small narrow areas below and behind the stigmal vein hairless. Marginal hairs regular, a little longer at the lower end, where they are still shorter than half the greatest width of the wing. Hind wings petiolate, narrow, with margins almost parallel ; marginal hairs three times as long as the width of the blade. Legs slender and long ; tarsi with four joints. Abdomen short oval, much shorter than the thorax. Ovipositor not protruding.

♂. Similar to the female, but the antennae much longer than the body, with 13 joints; scape slightly broadened in the middle; pedicel a little longer than broad; 1st funicle joint very small, annuliform; all the following 10 joints subequal in length, about four times as long as broad.

Length, ♀♂, 0.85–1.0 mm.

TRANVAAL: Pretoria, 22 ♀♀, 15 ♂♂, ix. 1926.

Host. From eggs of *Gonipterus scutellatus*, Gyll., from material sent from Australia.

This parasite of the gum-tree weevil has been discovered in Australia and introduced into South Africa, where it seems to be now established. According to Miller (N.Z. Jn. Agr., xxxv, 1927, p. 283) it has also been sent from Australia to New Zealand, where a second egg-parasite of the weevil has been bred.

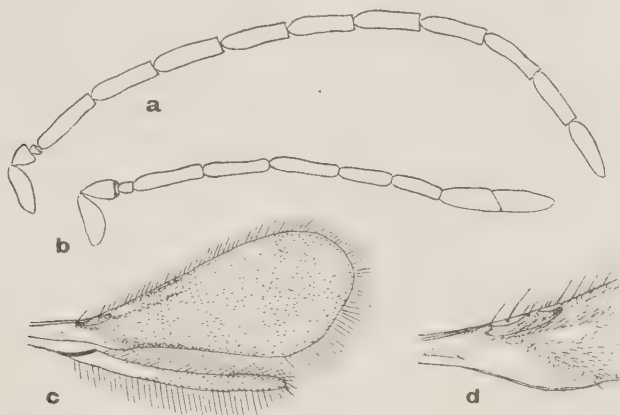


Fig. 3. *Anaphoidea gonipteri*, sp. n.: a, antenna of ♂; b, antenna of ♀; c, wings; d, base of forewing.

Four other species of *Anaphoidea* have already been described by Girault from Australia, each from single specimens taken by sweeping or on windows. As far as can be ascertained from the short descriptions, *A. gonipteri* may be distinguished from the other Australian species by the following key:—

1. Wings hyaline, as broad as in *Stethynium*; 2nd funicle joint globular, much shorter than 3rd; body black with a broad whitish band around base of abdomen ... *A. harveyi*, Gir.
- Wings more or less infuscated, at least at base; 2nd funicle joint not shorter than 3rd; body quite black ... 2.
2. Wings hyaline with slightly infuscated transverse stripes below the marginal and submarginal veins; funicle joints (except the small 1st) almost equal in length, the 2nd a little longer than the 3rd, the 6th the shortest ... *A. gonipteri*, sp. n.
- Wings uniformly infuscated, except at base ... 3.
3. Legs pale yellow, funicle joints short ... *A. linnaci*, Gir.
- Legs dusky, subpallid at trochanters; funicle joints elongate ... 4.
4. Second funicle joint distinctly longer than 3rd ... *A. galtoni*, Gir.
- Second and 3rd funicle joints equal in length ... *A. australia*, Gir.

A. gonipteri differs also from the other European and North American species in the coloration and form of the forewings and in the relative lengths of the antennal joints.

Anagrus cicadulinae, sp. n. (fig. 4).

♂♂. Body entirely yellow or orange-yellow. Antennae and legs paler. Eyes and ocelli reddish.

♀. Head a little broader than the thorax. Ocelli forming a small triangle, the distance between them shorter than their own breadth and much shorter than their distance to the eyes. Eyes almost rounded, cheeks large. Antennae inserted in the middle of the face, with 9 joints; scape somewhat broadened in the middle; pedicel as broad as the scape, but shorter, about twice as long as broad; 1st funicle joint very short, half as long as the pedicel and narrower; 2nd joint elongate, almost as long as the scape and more than four times as long as broad; 3rd a little shorter than 2nd; the following joints subequal in length, longer than the 2nd and broadening slightly

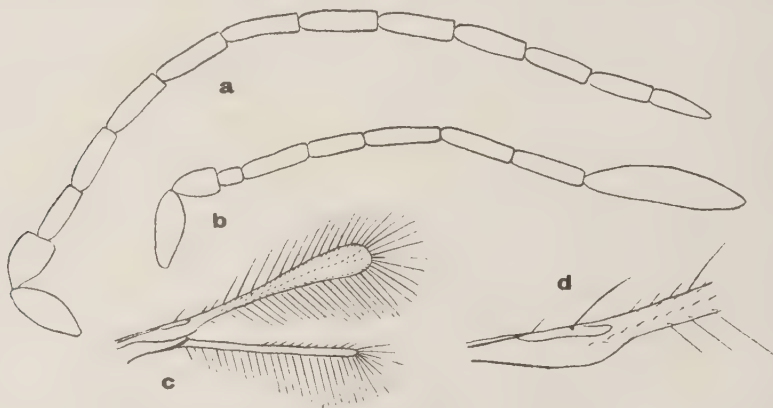


Fig. 4. *Anagrus cicadulinae*, sp. n.: a, antenna of ♂; b, antenna of ♀; c, wings; d, base of forewing.

toward apex, the 6th more than three times as long as broad; club ovate, a little longer than the two preceding joints together. The length of the joints (in 1/1000 of mm.) as follows: 62, 36, 20, 53, 45, 58, 56, 56, 122. Thorax narrow, elongate. Prothorax strongly narrowed in front; mesonotum longer than broad, with distinct parapsidal furrows; scutellum short, transverse, truncate posteriorly; propodeon large, longer than the scutellum, the spiracles small and oval. Wings narrow, longer than the body, only a little broadened and rounded at apex; marginal vein at the first quarter of the wing, short; stigmal vein in a straight line with the marginal, and little differentiated from it. The discal cilia sparse, except near the end where they are more dense; marginal hairs very long; at the lower end they are three times as long as the greatest width of the wing. Hind wings almost as long as the fore wings, but very narrow, linear, and petiolate at base; marginal hairs about six times as long as the width of the wing. Legs slender; tarsi as long as their tibiae, with four joints. Abdomen as long as head and thorax united, very much pointed at the end, the ovipositor slightly protruding.

♂. Similar to the female. Antennae with 13 joints; scape short, oval, about twice as long as broad; pedicel of the same breadth, but shorter; 1st funicle joint as long as the pedicel, but distinctly narrower; 2nd joint a little longer; the following 9 joints subequal in length, only the last shorter. Abdomen not longer than the thorax.

Length, ♀ 0.55 mm., ♂ 0.45 mm.

NATAL: Durban, 8 ♀♀, 2 ♂♂, 27.iii.1925 (C. P. van der Merwe).

Host. From eggs of *Cicadulina (Balclutha) mbila*, Naudé, on *Zea mays*.

This Jassid egg-parasite, the first of this genus from Africa, is very similar to *Anagrus armatus*, Ashm., another widely distributed parasite of JASSIDAE. It may, however, be separated from it by the following characters, taking the description of *armatus* given by Girault (Trans. Amer. Ent. Soc., xxxvii, 1911, p. 289).

A. armatus, Ashm.

Body more or less shaded and dusky above on thorax and abdomen.

Antennae with scape as long as the following three joints combined.

Second funicle joint longer than 3rd, and distinctly longer than 6th, which is sub-equal in length to 3rd.

Forewings enlarging distad to a pear-shaped apical head, the discal ciliation forming 5-6 longitudinal lines before apex.

The longest marginal cilia 1.75 times as long as the greatest wing width.

A. cicadulinae, sp. n.

Body uniformly orange-yellow.

Scape shorter than the two following joints combined.

Second funicle joint longer than 3rd, but shorter than 6th, which is distinctly longer than 3rd.

Fore wings less broad distad, the discal ciliation forming three longitudinal rows.

The longest marginal cilia 2.5 times as the greatest wing width.

***Alaptus andersoni*, sp. n. (fig. 5, a & b).**

♀. Body brownish, clearer on vertex and on middle of thorax, almost black between the ocelli and near the tip of the abdomen. Antennae and legs clear yellow, club more brownish. Eyes and ocelli dark reddish.

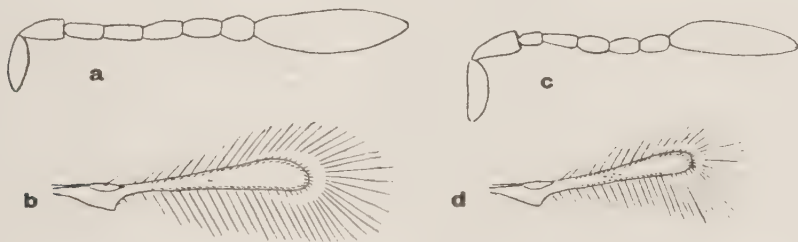


Fig. 5. *Alaptus andersoni*, sp. n. : a, antenna of ♀; b, forewing. *Alaptus caecilii*, Gir. c, antenna of ♀; d, forewing.

♀. *Head* as broad as the thorax; vertex broad, with the ocelli forming a low triangle, the lateral ocelli very near the occipital margin of the vertex and as far from the eyes as their own breadth. Between the eyes and the ocelli runs the ordinary carina of *Alaptus*, alternately black and white; the transverse carina above the frons largely black in the middle and clearer only near both ends; behind the head the carina follows the posterior margin of the eyes. Antennae relatively long, a little longer than the body, with 8 joints; scape with one side straight, the other strongly rounded, somewhat broader than the pedicel; pedicel about as long as two-thirds of the scape; 1st funicle joint narrower, but not much shorter than the pedicel; the following joints widening gradually, all of about the same size as the 1st, except the 5th which is shorter and rounded; club large, oval, as long as the four preceding joints together. The length of the joints (in 1/1,000 of mm.) as follows: 44, 31, 29, 29, 29, 29, 27, 116. *Thorax* short, rounded, as long as broad, almost smooth; the parapsidal furrows very faintly indicated. Wings very long, almost one and a half times as long as the body; with the ordinary form for the genus, the posterior margin denticiform near the base and the marginal vein elongate. The longest marginal cilia about three times as long as the width of the wing; along the inside of the margin of the

wing a narrow brownish stripe with small cilia, the disc itself quite hyaline with a single small hair in the middle. The white ring, formed by the decolorated base of the marginal cilia around the end of the wing, well marked. Hind wings narrow, not much shorter than the fore wings; on the hind margin the marginal cilia have the same length as those on the fore wings; disc with a single row of short cilia. Legs slender and long. *Abdomen* shorter than the thorax, rounded at the end. Ovipositor protruding, almost as long as one-third of the abdomen.

Length, 0.28 mm.; wing expanse (excluding cilia), 1.0 mm.

KENYA COLONY: Kabete, 3 ♀♀, vii. 1917 (*T. J. Anderson*).

Host. Reared from eggs on coffee leaf. The small eggs, which have been preserved with the parasites, are laid in a cluster of 34 near the middle rib of the leaf; they are the eggs of a Psocid.

This species, the first of the genus found in Africa, may be distinguished by its small size, with relatively long antennae and wings, by its coloration, by the relative length of the antennal joints, and by the presence of only one small discal cilia on the fore wings.

***Alaptus caecilii*, Gir. (fig. 5, c & d.).**

Alaptus caecilii, Girault, Ann. Ent. Soc. Amer., i, 1908, p. 189.

We have another species from Africa, which we are not able to distinguish from the American *A. caecilii*, Gir., when comparing it with the original description of the species. It differs specially from the preceding African species in the following characters.

Body entirely yellow; antennae and legs concolorous; eyes and ocelli reddish. Antennae shorter than the body; pedicel broad, two-thirds the length of the scape and twice as long as the 1st funicle joint, which latter is distinctly shorter than all other joints; 2nd joint about 0.75 times as long as the pedicel, and as long as the 3rd; 4th and 5th a little shorter than the 3rd and subequal in length; club as long as the combined lengths of three preceding joints together with about half the 2nd joint. The length of the joints (in 1/1,000 of mm.) as follows: 51, 36, 20, 27, 25, 24, 24, 87. Fore wings as long as the body, with a row of four discal cilia.

Length, 0.32–0.37 mm.; wing expanse (excluding cilia), 0.90 mm.

KENYA COLONY: Doindu, 6 ♀♀, iv. 1926 (*T. W. Kirkpatrick*).

Host. "Bred from coffee prunings attacked by Coccid."

As is known, many Psocids live among the Coccid colonies, and this species is very probably, like the American *caecilii* and other species, a parasite in eggs of PSOCIDAE.

Family SCELIONIDAE.

***Scelio zolotarevskyi*, sp. n. (fig. 6).**

♀♂. Body black, partly covered with small white cilia, especially behind the eyes and on the sides of the prothorax, propodeon and abdomen; on the propodeon they are shorter, thinner and more dense. Antennae of ♀ with scape and pedicel reddish brown, flagellum black; of ♂ with the flagellum orange-yellow, the scape and pedicel more brownish red. Legs reddish, only the coxae black, the posterior femora of ♀ somewhat brownish in the middle. Fore wings of ♀ slightly infusate, hyaline at base; wings of ♂ entirely hyaline.

♀. *Head* large, seen from above twice as broad as long, a little broadened behind the eyes; occiput largely excavated. Seen from in front, the head is rounded, the inner eye margin diverging downward; cheeks a little longer than half the length of the eyes. Anterior ocellus situated above the front, lateral ocelli on the vertex

near the eyes. Face and vertex irregularly but strongly reticulated. Antennae inserted above the clypeus, on each side of a chitinous protuberance; scape elongate, but not reaching the front ocellus; pedicel two and a half times as long as broad, about as long as one-fourth of the scape; 1st joint of the flagellum as long as the pedicel, but narrower, not much broadened at the tip; the following joints form a large club of nine joints, broader in the middle than at the ends; all the club joints transverse, the 1st small, the following of the same length but broader, the 4th distinctly larger than the others. *Thorax* longer than broad, strongly reticulated. On the mesonotum the longitudinal carinae are stronger and more regular than the transverse; the parapsidal furrows indicated by a row of grooves bordered by a stronger carina. Scutellum as strongly reticulated as the mesonotum. Meso- and metapleurae with a finer structure, the reticulation smaller than on the mesonotum. Metanotum with a row of large grooves separated by transverse carinae. Propodeon strongly reticulated anteriorly, the sides covered with dense small hairs; posteriorly it is hollowed, with few longitudinal carinae, and with a large truncate tooth on each

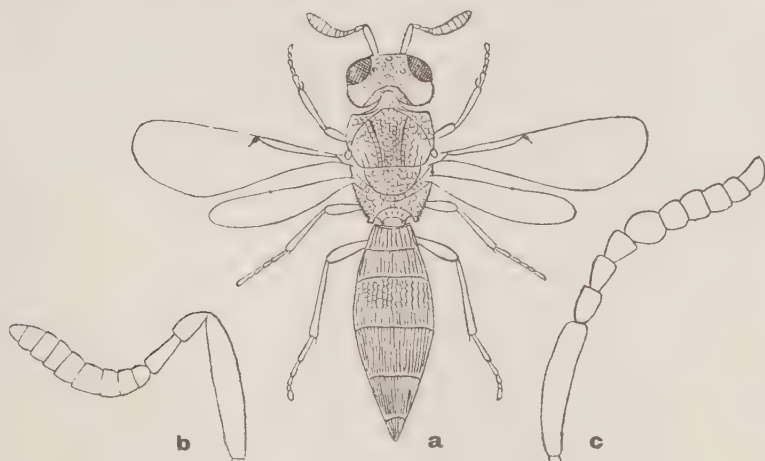


Fig. 6. *Scelio zolotarevskyi*, sp. n.: a, adult ♀; b, antenna of ♀, and c, of ♂.

side. Wings slightly infuscated, covered with brownish cilia, except at base which is hairless. Submarginal vein not reaching the anterior margin but ending in a sort of stigma formed by the thickened, rounded marginal vein, from which emerges the stigmal vein; the latter almost as long as the diameter of this stigma. The other veins indicated by folds in the wing. At rest, the wings do not reach the end of the abdomen. Hind wings large, quite hyaline. Legs short, femora a little thickened in their apical half. Pilosity very sparse on the femora, denser on tibiae and tarsi. *Abdomen* oval, elongate, distinctly longer than head and thorax combined. First segment short, transverse, truncate anteriorly; 2nd broader but little longer; 3rd almost twice as long as 2nd; 4th as long as 3rd but narrower; 5th shorter and narrower; 6th short and triangular; 7th very small. Each segment longitudinally striate from base to end, except for a narrow smooth band along the hind margin of the segments; the 1st segment with about 11 longitudinal striae, the 2nd with about 15 finer striae, the following segments with the striae thinner and closer together. These longitudinal striae are formed by regular carinae, between which are small transverse carinae, generally very thin, except at the base of the 3rd segment where the structure is more reticulated. Ovipositor not protruding.

♂. Quite similar to the female in size, coloration and reticulation of the body. Abdomen a little shorter and rounded at tip. The essential difference is only in the form of the antennae: scape straight, somewhat enlarged at the end; pedicel about twice as long as broad; 1st funicle joint slightly longer and broader than the pedicel; 2nd shorter but still broader, cupuliform; 3rd larger than all other joints, as long as the 1st, but more than twice as broad, rounded; the following joints shorter than broad, rounded at the sides; last joint pyriform, pointed at tip.

Length, ♀ 5.7 mm., ♂ 5.5 mm.

MADAGASCAR: Ejeda, 9 ♀♀, 1 ♂, and some pupae, 18.ii.1928 (*B. Zolotarevsky*).

Host. From eggs of *Locusta migratoria*, L., subsp. *migratorioides*, R. & F.

These parasites were sent by Mr. Zolotarevsky to Mr. B. P. Uvarov, from whom I received them for study.

All species of *Scelio* are probably parasitic in eggs of ACRIDIDAE, and other species have already been bred from eggs of *Locusta migratoria*, L., in different countries.

This species seems to be specially related to the African *S. howardi*, Crawf., from the Zambesi River, a parasite of *Nomadacris septemfasciata*, Serv. It may, however, be distinguished by the larger size, the coloration of the antennae and legs, in which the scapes and femora are almost quite reddish and only the hind femora brownish in the middle, the 9-jointed antennal club, the distinct parapsidal furrows, the scale-like hairs which are scattered over the head, thorax, and sides of abdomen, and by the clear brown fore wings with hyaline base.

NEW INJURIOUS HISPINAE.

By S. MAULIK.

The following notes are based on material submitted to me for study by the Imperial Bureau of Entomology. The drawings were made by Mr. D. E. Kimmins.

***Craspidonispa saccharina* sp. n. (fig. 1).**

Body oblong, very slightly broadened behind. Subnitid above. General colour black; lateral areas on the pronotum pinkish red; underside of prothorax and legs (except middle and hind tibiae), explanate margins of pronotum, prosternum partly, intercoxal process of the prosternum, lateral margins of abdominal sternites, a narrow lateral margin near the apex of each elytron, whitish; coxae partly fuscous and partly brownish or whitish; interocular space brownish; a little area on each shoulder, and the upper surface of all the claw segments of tarsi, brownish white; the black colour on the upper side of the femora narrow, broadening in the middle.

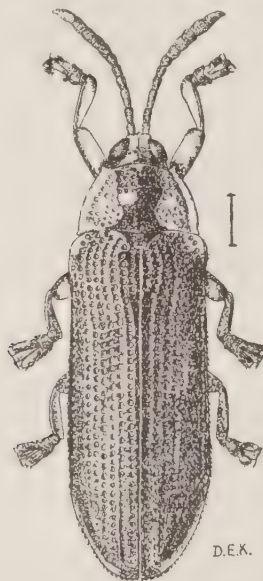


Fig. 1. *Craspidonispa saccharina*, sp. n.

Head with the apex smooth and shagreened; the collar behind the eyes, shining; interocular space rough with a deep longitudinal channel, a narrow margin on the inner side of each eye also channelled. Eyes fairly large, convex. Clypeus large, longer than broad, surface slightly convex, punctate. No projection between the antennae. Antennae with the surface shagreened, covered with punctures, some of which are elongate, and having short stiff hairs; the first segment stouter but slightly shorter than second; third the longest; fourth and fifth about equal; sixth shorter than seventh; the antenna is thickest here, gradually becoming somewhat thinner again; eight, ninth and tenth about equal; eleventh longer and bluntly pointed. *Prothorax* broadest at base, narrowed in front; sides with the margins somewhat

explanate; each anterior lateral angle with a conical pore bearing a fine seta; posterior margin more or less straight; upper surface convex but not uniformly, having depressions on the mid-basal area and anteriorly; roughly and closely punctate, the punctures being large and sometimes elongate, especially those in front which have coalesced. A central black area is smooth, shining and almost without or with some fine punctures. *Scutellum* quadrate, almost as long as broad, sloping in front, imbedded in a cavity, surface finely shagreened. *Elytra* slightly broader at base than prothorax; margin on each side of scutellum somewhat raised. Each elytron has eleven longitudinal series of punctures including a long scutellar one. The rows are very closely placed, the punctures of one row touching those of the next. The punctures themselves are squarish and deep and have a light transparent appearance at the centre. The interstices are not raised, though the first and second from the suture are slightly so on the apical area. The suture is raised. The surface of both the longitudinal and transverse ridges forming the boundaries of the punctures is wrinkled. The lateral and apical margins are serrate. *Underside* smooth, more shining than upper side; abdominal sternites with fine scattered punctures and irregular transverse striations. Intercoxal process of the prosternum broadened behind and coarsely punctate. Tibiae finely channelled along the upper side; first segment of the tarsi small, next two bilobed; claws strong, close to each other.

Length, 7 mm.; *breadth* a little more than 2.5 mm.; *length of antenna* 3 mm.

TRINIDAD: on sugar-cane (F. W. Ulrich).

Type in the British Museum.

Described from one example.

***Xenochalepus mucunae* sp. n. (fig. 2).**

Body oblong, subparallel-sided, slightly widened behind. General colour opaque black, but certain variable areas of brown or yellow-brown occur. Head and antennae black; prosternum and two lateral oblique stripes on the pronotum yellow-brown, so that the sides of the prothorax and a broad stripe narrowing anteriorly along the middle line on the pronotum are black; basal one-fourth of all femora but not the coxae yellow-brown; this appears to be more constant than the distribution of the yellow-brown colour on other parts of the body; lateral margins of abdominal sternites yellow. Scutellum black. The elytra may be entirely black with the exception of a narrow yellow-brown area on the humerus, or the latter colour may spread over half of the elytra in an ill-defined manner; but it must be noted that the area enclosed between the two principal costae of the two elytra including the suture is always black or only towards the base piceous. The foregoing description has been made from three specimens only, and the coloration of the species will probably prove to be highly variable.

Head somewhat oblong, with the collar smooth, impunctate or at most with a few scattered punctures here and there, shining; eyes large occupying a considerable area of the head, but not strongly convex; interocular space slightly depressed, with longitudinal channels, one rather fine along the middle continued to the interantennal area, each of the other two as a sulcus lying close to the inner margin of the eye. There is a sharp ridge between the antennae, and on each side of this ridge below the antenna is a hollow; the ridge is continued to the clypeus, which latter is raised and longer than broad with the surface rough and covered with a few whitish hairs. The first segment of the antenna thicker than and about equal in length to the second; the third the longest; the fourth slightly longer than fifth; the sixth slightly shorter than fifth; from the seventh the segments are slightly thickened and about equal to each other, the last being somewhat longer and pointed. Seen under a high power the surface of the antennae appears to be rough, shagreened and furrowed. *Prothorax* subconical, being narrower in front and broader at the base; each side with a fine

margin; each anterior lateral angle with a seta-bearing pore. Upper surface with a large depression at base opposite the scutellum; finely shagreened and covered with coarse and shallow pits. *Scutellum* lying in a plane inclined forwards and surrounded by a depression, quadrate, shagreened. *Elytra* slightly broader at the base than the prothorax; somewhat drawn forwards at a point internal to the humerus; surface shagreened, punctate-striate, and each elytron with two prominent ribs and two other very short and weak ones. The first or most prominent rib is after two rows of punctures from the suture and is of some height, with its surface shining and not shagreened. The second prominent rib commencing below the humerus almost reaches the apical margin. One of the short and feeble ribs commencing from the humerus extends only to a little distance, the other being on the apical area nearer to



Fig. 2. *Xenochalepus mucunae*, sp. n.

the second prominent rib. Each elytron with ten rows of punctures and a short scutellar row: between the suture and the most prominent rib two rows; between this rib and the next complete one six rows, the arrangement of which tends to become irregular in the middle area; between the second complete rib and the margin two rows. The punctures on the marginal area are larger than those on the rest of the surface. Suture not raised. The lateral margins dentate as shown in the figure; the teeth or spinules do not extend to the base of the elytra. *Underside* smooth, shining, impunctate, some parts finely shagreened; legs long and slender; femora without spines or spinules; tibiae somewhat broadened at the apex; claw-segment of the tarsus projecting a little beyond the previous bilobed segment; claws strong and close to each other.

Length slightly less than 8 mm. ; *antenna* slightly less than 3 mm.

BRAZIL : Bahia, 1929, on the leaves of *Mucuna pluricostata* (Dr. G. Bondar).

Type in the British Museum.

Described from three examples.

Codiohispa, gen. n.

This genus resembles *Probaenia*, Weise, in general form, but differs from it : (1) in having the punctures arranged differently ; (2) in having the costae different ; (3) in not having the spines on the underside of the femora.

GENOTYPE : *Codiohispa anonicola*, sp. n.

Range : Brazil.

I take here the opportunity to remark that the authorship of the allied genus *Uroplata* cannot be ascribed to Baly, because in his note on it in *Ann. Mag. Nat. Hist.*, 1864 (2), p. 335, he did not characterise the genus but merely pointed out the difficulty of doing so. The first author to characterise the genus was Chapuis (*Gen. Col.* xi, 1875, p. 319), but he did not fix the genotype. In drawing up the generic description, Chapuis refers to Guérin-Ménéville, who described four species under the name *Uroplata* (*Icon. du Règne Ann.*, iii, p. 274), without describing the genus. Three of these species have been made the genotypes of other genera, the fourth, namely, *vicina* (Bolivia), becomes the genotype of *Uroplata*. In Scudder the entry "*Uroplata*, Chevrolat, 1834" is copied from Agassiz, who does not give any reference to a published work in which Chevrolat's diagnosis of the genus can be found. Scudder's entry has therefore no standing so far as I can find out.

Codiohispa anonicola, sp. n. (fig. 3).

Body oblong, expanded at the base, then narrowed and again expanded at the external apical angles of the elytra. General colour shining yellow-brown ; two basal segments of antennae piceous, the rest reddish brown ; on each side of the pronotum commencing from a point opposite the humerus is a fairly broad blackish stripe which extends obliquely to the eye across the collar, staining the latter ; the two stripes thus converge in front : the apical half of middle femur blackish ; on the elytra is a pattern of blackish colour which in certain lights has greenish bluish tints. The pattern is as follows : a broad band along the basal margin (but without staining the scutellum) and the humerus extending to the lateral edge and turning obliquely inward, meeting the sutural stripe at two places and continuing to the extremity of the lateral apical expansion of the elytra. This continuation of the basal band covers the second costa and a row of punctures on each side of it. The suture and one row along it on either side are blackish, but at the places where the median stripe meets the sutural stripe two rows are covered by the colour. Across the apical area is a band joining the two expansions at the apical external angles of the elytra. The colour of the sutural stripe is less intense, and that on the marginal areas is the deepest. This particular distribution of colours on the elytra has the effect of making the yellow-brown areas stand out more prominently. The intensity of the colours varies to a certain extent, for example, the piceous colour is much lighter in some examples.

Head oblong, rounded in front with the eyes fairly large, but not strongly convex ; clypeus raised, longer than broad ; interocular space more or less plane ; antennae eight-segmented, not extending beyond the base of the pronotum, gradually thickened towards the apex ; the apical segments more covered with whitish hairs than the basal segments. *Prothorax* conical, narrower in front than at the base, sides indistinctly margined ; each anterior lateral angle with a little rounded projection ; upper surface coarsely punctate, basal margin longitudinally excavated in front of the

scutellum. *Scutellum* triangular with the apex rounded. *Elytra* much broader at the base than the prothorax, punctate-striate and ribbed; lateral margins finely serrate; apical margin more prominently serrate and truncate. A short scutellar row is represented by two or three punctures. On each elytron the rows of punctures are arranged in such a way that ten rows can be counted across the base, eight across the middle, and again ten across the apical area, but owing to the irregularity of the punctures these numbers are not constant in all examples. The punctures are large and squarish, and often coalesce with each other, thus producing a certain irregularity in the arrangement of the rows. There are three principal costae on each elytron, which are not well defined; on the apical area all interstices between the punctures are costate; the costa next to the suture is broad and most prominent. It cannot be said that the elytron is more than three-ribbed. The suture is raised. *Underside* smooth. Legs long, slender; all femora without a trace of any tooth or spine; mid tibiae inwardly curved; the claw segment not projecting beyond the bilobed segment; claws strong, close to each other.

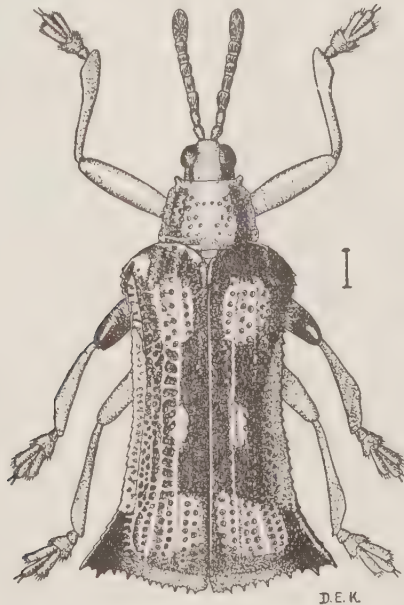


Fig. 3. *Codiohispa anonicola*, sp. n.

Length, 5 mm.; width across the apical area including the expansion, 3 mm.; across the base, 2.25 mm.; across waist, 2 mm.; length of antennae, 1.75 mm.

BRAZIL: Bahia, on leaves of *Anona squamosa*, L. (Dr. G. Bondar).

Type in the British Museum.

Described from eleven examples.

***Cnestispa*, gen. n.**

The species belonging to this genus resemble those of *Acanthodes*, Baly, but differ from them: (1) in being generally small; (2) in having the antennae differently

shaped, shorter and more than three-segmented ; (3) in having a short scutellar row of punctures ; and (4) in having the external apical angles more expanded and not produced as a spine.

GENOTYPE : *Cnestispa darwini*, sp. n.

Range : Brazil, Panama.

***Cnestispa darwini*, sp. n. (figs. 4, 5 B).**

Body small, almost parallel-sided, slightly broadened behind. Subnitid. General colour black with purple, steel-blue and greenish tints which are prominently visible when the insect is held at certain angles ; legs brownish yellow, tarsi and coxae smoky.

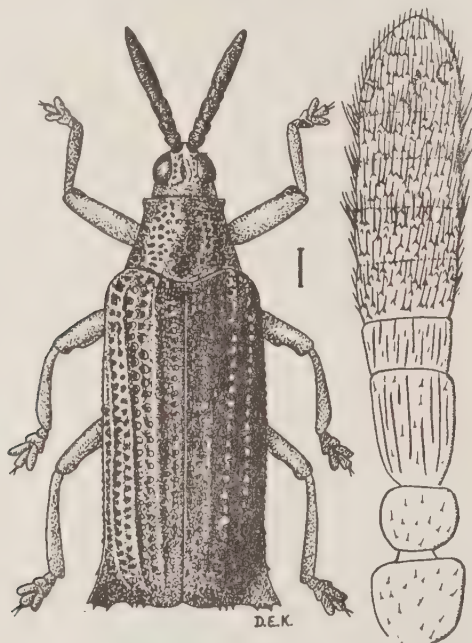


Fig. 4. *Cnestispa darwini*, sp. n., and antenna enlarged.

Head narrower than the prothorax ; interocular space rough, deeply and broadly channelled along the middle ; clypeus prominently raised, with the surface rough. Antennae short, hardly extending to the base of the pronotum ; not produced to a sharp point at the apex as in *Acanthodes* ; nine-segmented, first and second segments distinct, the former being larger than the latter ; third to ninth forming an elongate and slightly flattened club ; the third the longest ; fourth to eighth about equal to each other ; ninth broadened at the apex. The surface of the antennae is rough and appears to be scarred, the club being provided with very short bristles. The sutures between the segments that form the club are visible in a suitable microscopic preparation ; even then the suture between the two apical segments is not apparent. The following characters can be seen under a high power : The third and fourth segments show the scarred character better, while they apparently do not contain the bristles ; the fifth and the following segments are thickly covered with bristles ; on the last segment sensory pits are visible, though they are not well defined. I have already remarked on the relation between the reduction in the number of segments of the antennae and the occurrence of sensory pits. In the drawing the enlarged antenna is shown with the flattened side up, while in the whole figure the apex of the

antennae represents the sharper edge. *Prothorax* subcylindrical, narrowed in front; each side with a margin; each anterior lateral angle with a pore bearing a fine seta; basal margin bisinuate; upper surface closely and coarsely punctate, the basal area being somewhat depressed in the middle. *Scutellum* rectangular, broader than long, with surrounding area excavated; surface apparently convex, shining, smooth, impunctate. *Elytra* broader at the base than the prothorax. Each elytron with four pairs of longitudinal series of deep punctures, the intervals between them being raised, the alternate ones more so; suture raised; on the apical area all the intervals seem nearly equally raised. The third pair of rows (counting from the suture) is somewhat irregular behind the middle, there being a few more punctures tending to form a short row. All punctures are deeply impressed. Apical margin of elytra truncate and serrate. Lateral margin serrate. The arrangement of the spinules of the truncate posterior margin varies to a certain extent. I believe the form of the posterior lateral apical angles of the elytra to have specific value. In the present species they are somewhat expanded, concave and bear spinules. *Underside* smooth, abdominal sternites more shining than the upper side; very finely shagreened and with a few scattered minute whitish hairs. Legs slender; mid tibiae often bent inwardly; claws strong, closely placed.



Fig. 5. Apex of left elytron, showing arrangement of marginal spinules: A, *Cnestispa acuminata*, sp. n.; B, *C. darwini*, sp. n.

Length, type specimen 4 mm.; one example from S. Martha about 5 mm., and the example taken by Charles Darwin 4.5 mm.

BRAZIL: Bahia (*C. Darwin*); Bahia, 1928 (*Dr. G. Bondar*), on *Cymbotoma*; S. Martha.

Type in the British Museum.

Described from five examples. A single specimen from S. Martha and one taken by Darwin, although slightly larger, are referred to this species.

***Cnestispa acuminata*, sp. n. (fig. 5 A).**

Body small, oblong, parallel-sided. The external apical angles of the elytra are more pointed than in *Cnestispa darwini*, which this species very closely resembles.

These acute expansions are somewhat concave. Colour black with bluish and greenish tints, which are more clearly recognisable when the insect is held at certain angles. Legs yellow-brown, coxae and tarsi smoky or fuscous.

Length, 4 mm.

BRAZIL : Para.

Type in the British Museum.

Described from one example.

As indicated above, I separate this species from *C. darwini* by the acuminate character of the elytral external apical angles, which, I believe, is a good specific character.

***Cnestispa flavipes*, Baly.**

Acanthodes flavipes, Baly, Biol. Cent.-Amer., vi, 2, 1886, p. 118, t. 4, f. 25.

Eight examples including the type of this species are in the collection of the British Museum. On examination I find that this species should belong to the new genus proposed here. The external apical angles of the elytra are different in structure from those of the two preceding species.

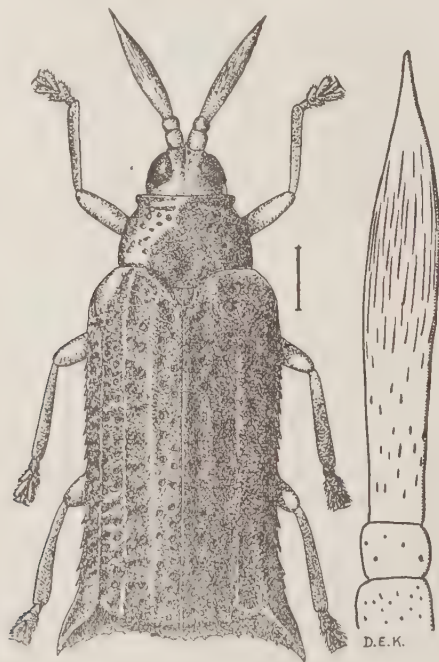


Fig. 6. *Acanthodes rana*, sp. n., and antenna enlarged.

***Acanthodes rana*, sp. n. (fig. 6).**

Body entirely deep red. Subnitid.

Head narrowed in front ; interocular space depressed, longitudinally channelled, and with a few punctures near the eyes, each puncture bearing a short whitish hair ; vertical area shagreened ; antennae three-segmented, with the two basal segments rounded, the first being somewhat larger than the second, the third segment somewhat

narrowed at the basal end and slightly dilated towards the apex, while the apex itself is drawn into a very sharp point; the surface of this slightly dilated portion is longitudinally ridged and shows faintly the sutures at which the segments have fused; the whole antenna punctate, bearing short whitish hairs. *Prothorax* subconical, narrower in front than at base; somewhat produced in front of scutellum, the sides rugosely punctate, the central area finely punctate, area in front of scutellum depressed and bearing mingled coarser and finer punctures; seen under a high power the whole background is very minutely punctate. *Scutellum* quadrate, situated in a cavity, the base bent down, the apex broadly rounded, the surface smooth, under a high power appearing to be very minutely punctate. *Elytra* broader at the base than the prothorax, parallel-sided, the lateral margins serrate; external apical angles of the elytra drawn into a sharply pointed triangular projection; surface finely shagreened; each elytron with four pairs of longitudinal series of deep and round punctures; between each pair the interspace is raised into a rib, but on the discal area the ribs are not pronounced but have become flattened and broad; on the apical area the ribs are stronger; the longitudinal series of punctures are irregularly arranged, two neighbouring punctures having frequently coalesced; the truncate apical edge serrate. *Underside*: the median area and the abdominal sternites more shining, the latter with very fine and scattered punctation; legs fairly long and slender; tarsal segments (except the basal one) bilobed.

Length about 8 mm.; *breadth*, 3.5 mm.; *antenna*, 2.5 mm.

BRAZIL, ex. Thomson Collection.

Type in the British Museum.

Described from one example.

In its uniform red colour this species differs from all others. In *Acanthodes donckieri*, Ws., which resembles this species in colouration, the prothorax and the tarsi are fuscous.

Gyllenhalius palmarum, sp. n. (fig. 7).

Body oblong, parallel-sided with the apex rounded; upper side flattish. General colour brown; apical area of elytra with an obsolescent, ill-defined blackish patch, which in some examples is more pronounced; eyes blackish; antennae and head dark red-brown or piceous, the apex of the inter-antennal projection paler; at the points of articulation of the segments of the legs the colour is somewhat darker.

Head broad, with the eyes convex; the interocular space not prominently raised, longitudinally depressed in the middle, coarsely and closely punctate, the punctures extending to the collar, which is otherwise smooth and impunctate. The inter-antennal projection is a solid structure, being as broad at the base as at the apex; viewed laterally it gradually narrows from base to apex; the upper and lateral surfaces are deeply concave, while the ventral is almost flat or at most very shallowly concave in the middle; upper surface is closely and coarsely punctate, the ventral being covered with a mixture of coarser and finer punctures; seen dorsally, the apex is rounded and upturned. Antennae extending a short distance beyond the base of the pronotum, fairly thick; the six basal segments shagreened and covered with coarse punctures, each containing a short whitish scale-like hair; the remaining segments without coarse punctures but thickly covered with bristly hairs; the seventh segment may have a few coarse punctures; the apical segment somewhat flattened; the first segment the largest, longer than broad; second small, rounded, with the apex somewhat produced on the underside; third distinctly longer than fourth; from the fourth to the tenth the segments are nearly equal. *Prothorax* quadrate, almost as long as broad; front margin almost straight; posterior margin somewhat lobed in the middle; sides parallel but widely rounded at the anterior lateral angles; posterior

lateral angles acute and with a deep notch ; upper surface gently convex from side to side, irregularly covered with a mixture of finer and coarser punctures, which are not closely placed ; the coarser punctures deeper on the lateral area ; in some cases the median area is almost without any coarse punctures. *Elytra* slightly broader at the base than the prothorax, punctate-striate, each elytron having nine regular rows of punctures (including a scutellar row) at the base, and ten rows across the middle, the sixth row from the suture being divided into three rows ; all rows converge on the apical area, meeting in pairs ; under a high power the interstices between the

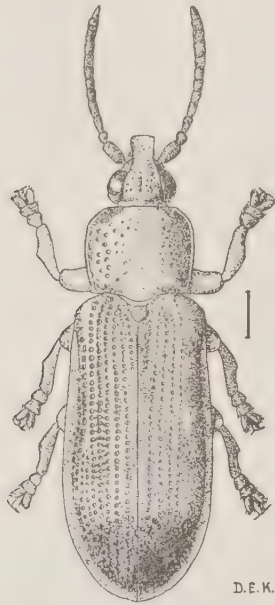


Fig. 37. *Gyllenhalius palmarum*, sp. n.

rows of punctures are seen to be very finely punctate ; lateral margins narrowly explanate. *Underside* somewhat more shining than the upper side ; abdominal sternites fairly closely punctate, finely shagreened ; legs short.

Length, excluding the interantennal projection, a little over 6 mm.

AFRICA : Gold Coast, Aburi, 18.i.1922 (*W. H. Patterson*), from oil palm and coconut leaves.

Type in the British Museum.

Described from five examples.

***Wallaceana phoenicia*, sp. n. (fig. 8).**

Body oblong ; upper side flat. Entirely brown, except the apical area of the elytra which is blackish, but in some examples the blackish colour is obsolescent. The antennae also blackish.

Head (viewed dorsally) compressed antero-posteriorly. Eyes and interocular space raised, the latter punctate and with a longitudinal impression in the middle.

Collar behind the eyes smooth, round and impunctate. The antennae with the first four segments finely punctate and shining; the fifth to the apex somewhat longer and pubescent; the first larger than the second; the latter more rounded than the third; the fourth shorter than the third; the remaining segments about equal to each other. *Prothorax* much broader than the head, almost quadrate; the anterior margin a little produced in the middle, where it is convex, and at each side deeply concave; lateral margins slightly sinuate. Upper surface covered with strong and scattered punctures; the longitudinal median area impunctate, but the lateral depressed areas with closely placed punctures; besides these large punctures there are extremely fine punctures on the interstitial spaces. *Scutellum* small, smooth, impunctate, the apex rounded. *Elytra* slightly broader than the prothorax, parallel-sided. On each elytron there are nine rows of punctures at the base and ten rows at

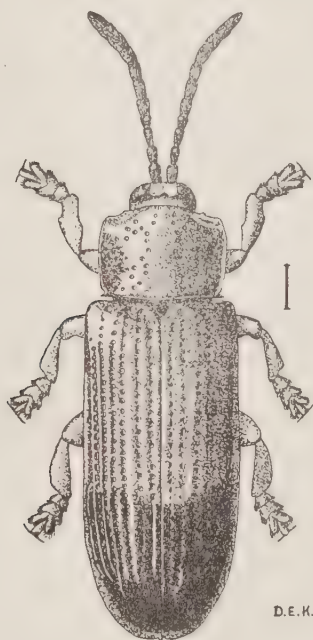


Fig. 8. *Wallaceana phoenicia*, sp. n.

the broadest part, the rows meeting in pairs towards the apex; no scutellar row. The punctures are large and rounded, and the interstices slightly costate, more so on the apical area. Under a high power the interstices are seen to be extremely finely punctate. *Underside* smooth, the abdominal sternites finely punctate. The legs are short, as usual in the genus; the claw segment projects a little beyond the bilobed segment; the claws are divaricate.

Length, 5.5 mm.

MALAY PENINSULA: Cary Island (G. H. Corbett and B. A. R. Gater).

Type in the British Museum.

Described from five examples, two bearing the date 5.i.1922 and found on *Oncosperma tigillaria*, of which the Malay name is "nibong"; this palm supplies

wood for building and also for pig spears. The other three examples before me—which are not in good condition—were collected on 10.i.1922 from another palm, *Zalacca conferta*, of which the Malay name is “kelubi.”

This new species of *Wallaccana* resembles very closely *W. palmarum*, Gestro, also from Malaya, but in the latter species the elytral punctures are stronger, the costae are more accentuated, and the antennae appear to be slightly more thickened towards the apex, with the apical segment not so pointed. These differences seem to be constant, but they may constitute a local variation. It is my opinion that all the species belonging to the genus *Wallaccana* which are entirely brown with a blackish patch on the apical area of the elytra, and which have a very wide distribution in India and in the Indo-Malay region, may be really one species with local variations or subspecies.

A KEY TO THE PRINCIPAL FAMILIES OF COLEOPTERA IN THE LARVAL STAGE.

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Introductory Remarks.

It is now more than twenty-five years since his useful "Key to Families of Coleopterous Larvae" was published by Macgillivray. Since that time descriptions of many larvae and representatives of a considerable number of families, then unknown, have been made available, and research on the taxonomy of families and super-families has added very considerably to our knowledge of the early stages of beetles. Without being invidious, it may not be out of place to mention the work of Saalas on spruce-beetles, of Verhoeff on several families and especially the Clavicorn group, of d'Orchymont on the HYDROPHILIDAE, of de Peyerimhoff on the larvae of several obscure families, and, not least of these, that of Böving made known in a number of papers on the species, families and super-families of this order of insects. These and many others, too numerous to mention here, but whose names will in most cases be found in the bibliography, have made notable additions to our knowledge since the publication of Macgillivray's work.

The time seems ripe therefore to make a further attempt to tabulate some portion of the results obtained in the form of a key, in spite of all the limitations which such a method entails. For it must always be borne in mind by one who seeks to use this method, that the primary purpose of a dichotomous key is the determination of species, genera, or families, and that the more scientific, if less obvious, characters must give way before the more obvious, if the latter are sufficient to attain the main object of determination. By reason of its very method it is not possible for a dichotomous key to give the full results of the study of comparative anatomy.

Following the axiom laid down above, the author has included in his first division of the key larvae either lacking legs, or whose legs are vestigial, although he is fully aware that such a division is not scientific, separating as it does the SPHAERIDIINAE from the rest of the HYDROPHILIDAE, and the LAMINAE from the other members of the CERAMBYCIDAE. There are also known individual species of families, such as *Hectarthrum* among the CUCUJIDAE (Gravely, 1916), which from the evidence, either of larval or adult characters, are obviously properly included in the families to which they are assigned but lack the legs possessed by other members of the family in the larval stage. Such isolated cases of independent larval evolution have not been separated from their families, being regarded as specific cases of adaptation, possibly of comparatively modern development.

The remainder of the principal divisions (B-E) have been suggested by consideration of Böving's "Larval Characters defining the Family Series Cleroidea" in his valuable joint paper with A. B. Champlain on the larvae of North American CLERIDAE (1920), though possibly not worked out as he would have designed.

In general the classification of Reitter, in his "Fauna Germanica," has been adopted as being that at once most generally accepted and readily accessible at the

present time. Some few exceptions have, however, been made, in cases where it seems essential to subdivide families recognised by Reitter. Such are the division of the family STAPHYLINIDAE into two new families of OXYTELIDAE and STAPHYLINIDAE (*sens. str.*) by Verhoeff; the new family SCALIDIIDAE separated from the CUCUJIDAE by Böving; and, provisionally, the separation of the BOTHRIDERIDAE from the family COLYDIIDAE by Craighead.

But, in spite of the many cases where groups of larvae possess characters inconsistent with those borne by others considered as typical of the family in the larval stage, it has been deemed wiser, pending a reconsideration of both larval and adult characters by competent authorities on a large scale, to preserve the classification of families adopted by Reitter. Neither of the main divisions D or E, though comprised of larvae having the characters given, must be considered as forming an exhaustive list of larvae bearing such characters, since some have been included previously in an earlier division founded upon another character. For example, division E is made up of larvae bearing a molar process at the base of the mandible, but before being included in this division a family or group must have been tested for the characters included in each of the preceding divisions A-D and have been found lacking in one at least of such characters. Thus the subfamily SPHAERIDIINAE, though possessing the molar process to the mandible, cannot be included in division E because the legs are not developed; the DASCILLIDAE, LUCANIDAE and SCARABAEIDAE are included in division C, because the body of the larva in each case is curved ventrally and this character precedes in order that of the presence of the molar process, which each of them possesses.

The main divisions A-E are separated from one another for convenience only, and in using the key it must always be borne in mind that mistakes are liable to occur unless the earlier divisions have first been found inapplicable to the larva being examined.

Certain few families, such as the PSELAPHIDAE, where no more than one species is known to have been described in the larval stage, and that not very adequately, have been reluctantly omitted. Further, the description of the larva of *Micropeplus* is not adequate to enable its position to be fixed. Its systematic position in juxtaposition to subfamilies of OXYTELIDAE, as determined by Ganglbauer (apparently with some hesitation), is a matter of considerable doubt. The interesting so-called "trilobite larvae," found first about a century ago and the full life-history of which has only recently been made known by Mjöberg, are also of uncertain position. He himself appears to regard them as Lycids, with the weighty support of Gahan, but if this is so, their characters differ widely, as do their habits, from those of the LYCIDAE hitherto described, and it has not been found possible to include them.

In other cases, however, such as *Cebrio* and *Callirhipis*, the description appears to be representative of the family, as we know it, and the family is included in the key, followed by the name of the genus on which its position there depends. Frequently it has been found necessary to divide families into two or more sections. The name of the family is then followed by the word *pars*, indicating that a part only of the family bears the characters given, the other part or parts being included elsewhere.

Figures in brackets refer back to a division occurring some distance before, where the character or characters of the group have first been separated from the alternative character or characters. The method has been used sparingly, and only in the longer divisions.

A semicolon (;) has been used to separate characters borne by different organs, a comma (,) to separate characters borne by the same organ.

A short list of definitions has been appended in order to make clear the meaning which the author attributes to such terms as appear to need definition. The figures are also intended to serve a similar purpose.

The bibliography is admittedly only in skeletal form, for reasons of time and space. But it is hoped that at least the most important of recent papers dealing with the families of beetles in the larval state have been included and that from these, from general systematic works, such as those of Ganglbauer and Seidlitz, or from bibliographies like those of Rupertsberger or Blunck, the reader may obtain such references as he requires for a further study of particular species.

The author desires to thank Dr. G. H. Carpenter, of Manchester, and Dr. R. E. Snodgrass, of the United States Bureau of Entomology, for permission, most kindly given in each case, to have copies made of figures previously published by them. He has, however, in most cases substituted reference-letters of his own for those of the original papers, and for this he is alone responsible. He would also thank those friends who have helped him by suggestions during the progress of his work, and in particular he would mention Dr. David Keilin, whose critical acumen has been of the greatest value, and Professor L. P. W. Renouf, who has most kindly read through the draft of the key and made valuable criticisms for the clarification of the text.

Finally, in submitting this key to his fellow-workers, he would emphasize the fact that all such productions must in their nature be, at best, of transitory value, if biological science continues to advance as it has done in the past century, and would express the hope that the life of his key may form no exception to the general rule.

Key to Larvae of Coleoptera.

- | | | | | | | |
|----|--|-----|-----|-----|---|----|
| A. | Thoracic legs present, usually well developed | ... | ... | ... | ... | B. |
| | Thoracic legs absent or vestigial | ... | ... | ... | ... | 1. |
| 1. | Body curved dorsally; mandible with prostheca | ... | ... | ... | PAUSSIDAE. | |
| | Body straight or curved ventrally; mandible without prostheca | ... | ... | ... | 2. | |
| 2. | Mouth-parts vestigial, mouth exceedingly narrow | ... | ... | ... | EUCNEMIDAE. | |
| | Mouth-parts developed, mouth wider | ... | ... | ... | 3. | |
| 3. | Body more or less depressed; vertex of head flattened; epignathous | ... | ... | ... | 4. | |
| | Body rounded; vertex rounded; hypognathous | ... | ... | ... | 6. | |
| 4. | Labrum absent; maxilla palpiform; abdomen having only 8 visible tergites | ... | ... | ... | HYDROPHILIDAE, <i>pars</i> (SPHAERIDIINAE). | |
| | Labrum present, free or fused with clypeus; maxilla having mala, not palpiform; abdomen with at least 9 visible tergites | ... | ... | ... | 5. | |
| 5. | Labial palps mere fleshy projections; prothorax large and forming a stout shield above and beneath; spiracles cribriform | ... | ... | ... | BUPRESTIDAE. | |
| | Labial palps 2-jointed; prothorax not so large and shield-like; spiracles oval, with longitudinal slit | ... | ... | ... | CERAMBYCIDAE, <i>pars</i> (LAMIINAE). | |
| 6. | Maxillary palp of 3 segments; labium straight on anterior margin | ... | ... | ... | ANTHRIBIDAE. | |
| | Maxillary palp of 2 segments; labium with anterior margin convex | ... | ... | ... | 7. | |
| 7. | Legs absent; maxilla curved on inner margin; anal segment bearing 4 lobes | ... | ... | ... | CURCULIONIDAE. SCOLYTIDAE. | |
| | Legs present but much reduced; maxilla nearly straight on inner margin; anal segment with transverse fold only | ... | ... | ... | BRUCHIDAE. | |
| B. | Thoracic legs each with combined tarsus and claw, or without claw | ... | ... | ... | C. | |
| | Thoracic legs each with definite tarsus and one, two, or three claws | ... | ... | ... | 8. | |
| 8. | Larvae undergo hypermetamorphosis; 1st instar spent as triungulin | ... | ... | ... | 9. | |
| | Larvae do not undergo hypermetamorphosis; without triungulin stage | ... | ... | ... | 10. | |

9. Triungulin larva has 3 claws at apex of each tarsus; parasitic on bees and Orthoptera MELOIDAE.
Triungulin-formed larva has only one claw to each tarsus, modified to form a sucker; parasitic on wasps and cockroaches RHIPHIPHORIDAE (*Emenadia*).
10. Tarsi each with one claw 11.
Tarsi each with two claws 15.
11. Labrum present, either distinct or as part of clypeo-labrum 12.
Labrum absent 14.
12. Mala maxillaris single, triangular; ocelli 3 on each side; with paired cerci OXYTELIDAE (Verh.) *pars* (*Bledius*).
Malae maxillaris two, or rudimentary; blind; without paired cerci ... 13.
13. Coxa provided with furrow for reception of legs; malae rudimentary RHYSODIDAE.
Coxa without furrow for reception of legs; galea and lacinia present CUPEDIDAE.
14. Inner tooth of mandible (retinaculum) present; galea palpiform; terrestrial CARABIDAE, *pars* (*Dyschirius*, *Broscus*, *Bembidium*, *Sphodrus*, *Aëpus*, *Cillenius*).
Inner tooth of mandible absent; galea broad; aquatic ... HALIPLIDAE.
15. Labrum well developed MICROMALTHIDAE.*
Labrum absent or concealed beneath frontal margin 16.
16. Mandible with blood channel; aquatic 17.
Mandible without blood channel; aquatic or terrestrial 18.
17. Abdomen consisting of 10 segments, including pseudopod; tracheal gills present on each abdominal segment GYRINIDAE.
Abdomen consisting of 8 apparent segments; tracheal gills absent, terminal spiracles being the largest DYTISCIDAE.
18. Legs adapted for swimming; thoracic and abdominal segments 1-3 with tracheal gills HYGROBIIDAE.
Legs not adapted for swimming; without tracheal gills 19.
19. Spiracles of 8th abdominal segment on dorsal surface; aquatic; onisciform AMPHIZOIDAE.
Spiracles lateral, in almost a straight line; terrestrial; linear or elongate 20.
20. Hooks attached to 5th abdominal tergite; cerci absent ... CICINDELIDAE.
No hooks attached to 5th abdominal tergite; paired cerci or pseudo-cerci present CARABIDAE, *major pars*
- C. Body straight (orthosomatic) or with dorsal surface forming a hump (cyphosomatic), not bent ventrally D.
Body curved or bent ventrally 21.
21. Functional spiracles present only in 8th abdominal segment; aquatic CHRYSOMELIDAE, *pars* (DONACIINAE).
Functional spiracles present in thorax and 8 abdominal segments; not aquatic 22.
22. Spiracles cribriform 23.
Spiracles not cribriform 26.
23. Labrum almost concealed beneath clypeus; epicranial suture V-shaped; short pseudocerci on 9th abdominal segment DASCILLIDAE.
Labrum distinct; epicranial suture Y-shaped; no pseudocerci 24.

* Legs are present in 1st instar only (Barber).

24. Antenna of two segments on basal process ; maxillary palps biarticulate ; third pair of legs each reduced to coxa and trochanter PASSALIDAE.
Antenna of three or more segments ; maxillary palp of 4 or more segments ; third pair of legs each of 4 segments at least 25.
25. Anal aperture longitudinal ; abdominal segments without transverse folds dorsally (*Sinodendron* has some indication of these) LUCANIDAE.
Anal aperture transverse (exc. *Serica*) ; most abdominal segments with two transverse folds dorsally (exc. *Geotrupes*) SCARABAEIDAE, *major pars*.
26. Larva forms a case in which it lives CHRYSOMELIDAE, *pars* (CLYTHRINAE and CRYPTOCEPHALINAE).
Larva free-living 27.
27. Lacinia well developed ; penultimate segment of antenna bearing a short process ; spiracles biforous 28.
Lacinia absent or, if present, very small ; antenna without accessory process on penultimate segment ; spiracles uniforous 29.
28. Cuticle of pronotum horny ; antennae short ; spiracular openings transverse BYRRHIDAE.
Cuticle of whole body soft ; antennae more than half length of head ; spiracular openings longitudinal SCARABAEIDAE, *pars* (*Trox*).
29. Anal fold transverse PTINIDAE.
Anal fold, if present, not transverse 30.
30. Mandible with large pseudo-molar process ; antenna of 4 segments ; legs 3-jointed ; 8th abdominal spiracle much largest LYCTIDAE.
Mandible without molar or pseudo-molar process ; antenna of less than 4 segments ; legs 4- or 5-jointed ; abdominal spiracles of nearly equal size 31.
31. Antenna extremely minute, invisible from beneath ; spiracles annuliform ANOBIIDAE.
Antenna distinctly visible from beneath ; spiracles bilabiate BOSTRYCHIDAE.
- D.** Mandible with mola or molar process at the base E.
Mandible without mola or molar process at base 32.
32. Mandible tapering from base to apex 34.
Mandible palmate, usually with 3-5 teeth anteriorly 33.
33. Antenna of two or three segments ; spiracles annular or annular-biforous ; 9th abdominal segment developed CHRYSOMELIDAE, *major pars*.
Antenna of single segment ; spiracles biforous ; 9th abdominal segment truncate, operculate RHIPICERIDAE (*Callirhipis*).
34. Labrum and clypeus present, though they may be fused together 43.
Labrum absent or rudimentary 35.
35. Mandible either spiniform or with blood channel, internal or running along the inner margin TELEPHORIDAE, *pars* (LAMPYRINAE ; LYCINAE, exc. *Homalilus* ; TELEPHORINAE).
Mandible not spiniform, without blood channel 36.
36. Eight abdominal segments visible dorsally ; metapneustic or apneustic ; mostly aquatic HYDROPHILIDAE, *maxima pars*.
Nine abdominal segments visible dorsally ; peripneustic ; terrestrial or aerial 37.
37. With paired processes at posterior end of 9th abdominal segment 38.
Without paired processes at posterior end of 9th abdominal segment 42.
38. Processes forming jointed cerci 39.
Processes fixed and horny 41.

39. Spiracles annular or oval, uniform, ... STAPHYLINIDAE, Verh. (STAPHYLININAE, QUEDIINAE, XANTHOLININAE, PAEDERINAE).
Spiracles biforous 40.
40. Mandible with penicillus at base, inner margin smooth ... HISTERIDAE.
Mandible without penicillus, inner margin serrated
HYDROPHILIDAE, *pars* (HELOPHORINI).
41. Antenna triarticulate; maxilla bearing galea and lacinia ELATERIDAE, *pars*
(AGRIPNINI, *Athous*, *Corymbites*, etc.).
Antenna uniarticulate; maxilla with single mala only THROSCIDAE (*Drapetes*).
42. Ocelli two; submentum linear; anal segment exerted
ELATERIDAE, *pars* (*Cardiophorus*, *Agriotes*, *Elater*, etc.).
Ocelli none; submentum obovate; anal segment very short
CEBRIONIDAE (*Cebrio*).
43. (34) With movable cerci on 9th abdominal segment 44.
Without movable cerci on 9th abdominal segment 46.
44. Moniliform, flattened; mandibles slender; cerci single-jointed
TRICHOPTERYGIDAE.
Not moniliform, usually campodeiform or onisciform; mandibles strong; cerci
unjointed or with one or two joints 45.
45. Prothorax at least double the width of the head; maxilla with galea and lacinia;
cerci 2-jointed SILPHIDAE, *pars* (SILPHINAE).
Prothorax narrower or a little wider than head (exc. *Syntomium*, which has
1-jointed cerci); maxilla with single mala; cerci with 2, 1, or no joints
OXYTELIDAE, Verh., *pars* (OXYTELINAE, OXY-
PORINAE, TACHYPORINAE, STENINAE, ALEO-
CHARINAE, OMALIINAE, PROTEINAE, DIGLOSSINAE).
46. Maxilla inserted on anterior margin of head, the margin of which may be slightly
(but regularly) excavated 47.
Maxilla inserted posterior to anterior margin of head, between the margins of the
epicranial plates 49.
47. Mandible with single-pointed apex; frontal sutures present 48.
Mandible with two or more denticles at apex; frontal sutures absent
SCALIDIIDAE, Böving.
48. Mandible tetragonal, distal end gouge-shaped; legs weakly developed; without
anal pseudopod CERAMBYCIDAE, *pars* (CERAMBYCINAE).
Mandible trigonal, distal end acuminate; legs usually well developed; with
anal pseudopod CLERIDAE, *major pars*.
49. With paired pseudocerci at posterior end of 9th abdominal segment ... 64.
Without paired processes at posterior end of 9th abdominal segment ... 50.
50. Mandible with blood channel ... TELEPHORIDAE, *pars* (DRILINAE, *Homalisus*).
Mandible without blood channel 51.
51. Respiration by means of functional spiracles 53.
Respiration by means of tracheal gills 52.
52. Tracheal gills protrusible from anal aperture PARNIDAE, *pars* (HELMINTHINAE,
Potamophilus, *Psephenoides*).
Tracheal gills on posterior border of abdominal segments 1-5 PSEPHENIDAE.
53. Tenth abdominal segment a flattened, horny, valve-like structure enclosing
the anus PARNIDAE, *pars* (*Dryops*, *Helichus substriatus*).
Tenth abdominal segment not a valve-like structure enclosing the anus ... 54.

54. Eight abdominal segments only visible from above; 8th pair of abdominal spiracles at posterior apex NOSODENDRIDAE.
 Nine abdominal segments visible from above; 8th pair of abdominal spiracles not at posterior apex of body 55.
55. Ninth abdominal segment produced in a median horny process posteriorly 56.
 Ninth abdominal segment not produced in a posterior process 57.
56. Process on 9th abdominal segment pointed, sometimes bifurcated; legs fleshy, peg-like MORDELLIDAE, *pars* (MORDELLINI).
 Process on 9th abdominal segment blunt at apex; legs corneous, kneed
 MELANDRYIDAE, *pars* (*Conopalpus*).
57. Length of 9th abdominal segment nearly equal to preceding 3 segments together
 MORDELLIDAE, *pars* (SCRAPTINIAE).
 Length of 9th abdominal segment not nearly equal to preceding 3 segments together 58.
58. Onisciform or acariform; penultimate segment of antenna much enlarged; pronotum equal to or exceeding the meso- and metanotum together in length
 SCYDMAENIDAE.
 Fusiform or linear; penultimate segment of antenna not greatly enlarged; pronotum scarcely as long as meso- and metanotum together, or less 59.
59. Maxilla with single mala 60.
 Maxilla with galea and lacinia 63.
60. Mandible bearing two teeth at apex; supplemental process on 1st segment of antenna COLYDIIDAE, *pars* (*Bothrideres*).
 Mandible with single-pointed apex or with 3 or more teeth at apex; supplemental process on 2nd segment of antenna 61.
61. Shape fusiform; without prehensile tubercles on body; supplemental process of antenna short 62.
 Shape eruciform; prehensile tubercles present on thorax and abdomen (exc. *Orchesia*); supplemental process of antenna long, nearly equal to or exceeding 3rd segment in length MELANDRYIDAE, *pars* (*Orchesia*, *Abdera*, *Melandrya*, *Hypulus*, *Dircaea*?, *Anisoxya*?, *Marolia*).
62. Mandible multidentate at apex; dorsal surface of larva bearing many branched setiferous processes COCCINELLIDAE, *pars* (EPILACHNINAE).
 Mandible with simple pointed apex; dorsal surface of larva bearing setae only
 CLAMBIDAE (*Calyptomerus*).
63. Body bearing a dense mass of hairs, frequently long and in bundles at posterior end; prothorax arched; spiracles uniform (9th abdominal segment is sometimes hidden) DERMESTIDAE, *major pars*.
 Body clothed with fine hairs, not in dense bundles; prothorax flattened; spiracles cribriform HETEROCERIDAE.
64. (49) Paired pseudocerci mere papillae, each bearing a seta at apex
 SCAPHIDIIDAE (*Scaphosoma*).
 Paired pseudocerci horny 65.
65. Body bearing dense outstanding hairs; maxilla bearing lacinia and 2-jointed galea DERMESTIDAE, *pars* (DERMESTINI).
 Body without dense outstanding hairs, though sometimes pubescent; maxilla bearing single mala only 66.
66. Antenna without supplemental process MORDELLIDAE, *pars* (ANASPINI).
 Antenna with supplemental process 67.
67. Process of antenna considerably longer than 3rd segment CISIDAE.
 Process of antenna not longer than 3rd segment 68.

83. The said process membranous and comb-like; maxillary mala with small internal process NITIDULIDAE, *major pars*.
The said process not comb-like; maxillary mala without internal process 84.
84. Process pointed and taking the form of a prostheca ... CRYPTOPHAGIDAE.
Process rounded NITIDULIDAE, *pars (Meligethes)*.
85. Antenna with distinct supplemental process attached to 2nd segment ... 86.
Antenna with supplemental process on 2nd segment represented by a small tubercle only MYCETOPHAGIDAE.
86. Mandible with small fleshy process at base of mola BYTURIDAE.
Mandible without such process 87.
87. Form elongate, cylindrical or subcylindrical; ocelli 2 to 5 on each side
COLYDIIDAE.
Form broad and flattened; ocelli absent MELANDRYIDAE, *pars (Stenotrachelus)*.
88. (80) Maxillary cardines not distinct from stipites 89.
Maxillary cardines distinct from stipites 90.
89. Antennae placed close to mandibular joints; dorsal surface of larva with setiferous tubercles or spines (exc. HYPERASPINI) COCCINELLIDAE, *major pars*.
Antennae placed considerably posterior to mandibles; dorsal surface bearing squamae CORYLOPHIDAE.
90. Prothorax thickened anteriorly to form a hood; mentum partially divided into two lobes anteriorly LYMEXYLONIDAE.
Prothorax not forming a hood; mentum not divided anteriorly ... 91.
91. Maxillary mala falciform or with uncus on inner margin 92.
Maxillary mala obtuse or rounded 95.
92. Head at least twice as broad as long, broader than prothorax 93.
Head not more than 1.5 times as broad as long, not broader than prothorax 94.
93. Labrum clearly separated from clypeus; 9th abdominal sternite bearing transverse row of small teeth at anterior margin PYROCHROIDAE.
Labrum incompletely separated from clypeus; 9th abdominal sternite without transverse row of teeth anteriorly CUCUJIDAE, *pars (CUCUJINI, PROSTOMINI)*.
94. With prominent pseudocerci on 9th abdominal tergite; anal segment not protruding posteriorly PYTHIDAE, *pars (Pytho)*.
Without pseudocerci on 9th abdominal tergite; anal segment extending far behind the 9th segment CUCUJIDAE, *pars (SILVANINI)*.
95. Eighth abdominal segment much longer than 7th; 9th abdominal segment bearing long pseudocerci CUCUJIDAE, *pars (LAEMOPHLOEINI)*.
Eighth abdominal segment little, if any, longer than the 7th; 9th abdominal segment with or without short pseudocerci 96.
96. Head with epicranial suture lyre-shaped, reaching to posterior margin, or else with suture not reaching to posterior margin 97.
Head with epicranial suture Y-shaped (V-shaped in *Agnathus*), the coronal portion reaching to posterior margin 101.
97. Labial palp consisting of one segment only
NITIDULIDAE, *pars (Ipidia, Brachypterus)*.
Labial palp of two segments 98.
98. Ninth abdominal segment bearing at least two hooks or pseudocerci ... 99.
Ninth abdominal segment without hooks or pseudocerci 100.
99. Ninth abdominal segment bearing 4 hooks posteriorly
PYTHIDAE, *pars (Rhinosimus, Lissodema)*.
Ninth abdominal segment bearing only two pseudocerci or hooks posteriorly
ENDOMYCHIDAE, *pars (MYCETAEINAE, SPHAEROSOMINAE)*.

100. Mandible with prominent tooth (retinaculum) anterior to mola SPHINDIDAE.
Mandible without retinaculum ENDOMYCHIDAE, *pars* (ENDOMYCHINAE).
101. (96) Legs placed wide apart; usually with paired pseudopods dorsally or ventrally on anterior segments (exc. *Oedemera*, *Stenostoma*); thoracic spiracle placed on process of prothorax OEDEMERIDAE.
Legs placed near together; without paired tubercles or pseudopods on anterior segments; thoracic spiracles placed in mesothorax 102.
102. Head perpendicular; hypognathous; body either broad, or narrow and somewhat flatly depressed LAGRIIDAE.
Head inclined; epignathous; body almost cylindrical TENEBRIONIDAE, CISTELIDAE.

Note.—Of the larvae known, the TENEBRIONIDAE frequently have short pseudocerci on the 9th abdominal segment, the CISTELIDAE are usually without them. But *Omophilus* (CISTELIDAE) possesses pseudocerci, and some genera of TENEBRIONIDAE (e.g., *Crypticus*, *Hypophloeus*, *Diaperis*, *Eledona*) lack any such processes.

Definitions.

GENERAL.

Acariform. Shaped like a mite (*Acarus*).

Campodeiform. A term applied to insect larvae that are active and shaped like *Campodea* (*Thysanura*), with well-developed legs (Tillyard).

Cerci. Appendages of the 9th abdominal segment, usually slender and jointed.

Hypermetamorphosis. A larva which passes through two or more markedly different instars in the course of its development is said to undergo hypermetamorphosis (Imms, *partim*).

Moniliform. Like a string of beads.

Onisciform. Shaped like a woodlouse (*Oniscus*).

Pseudocerci. Appendages of the 9th abdominal segment, taking various shapes, usually horny and always unjointed.

Triungulin. The larva of a Meloid in the first instar. It is campodeiform and bears apparently three claws on each foot, though probably only one represents a real claw (Packard).

HEAD.

Antenna. The antenna is commonly borne on a basal process. The segments are numbered from base to apex, excluding the basal process (fig. 5).

Epicranial suture. The suture which usually separates the two epicranial plates on the dorsal surface of the head. Anteriorly it is frequently forked into two branches, the frontal branches of the epicranial suture, on either side of the frons. The basal, sagittal portion is sometimes referred to as the metopic (Berlese) or coronal (Snodgrass) suture (fig. 4).

MOUTH-PARTS.

Epignathous. Having the mouth-parts directed anteriorly.

Hypognathous. Having the mouth-parts directed ventrally.

Mala maxillae. The lobes of maxilla; outer or galea, inner or lacinia; where only one is present, the term refers to that one (J. B. Smith).

Uncus. A hook-like process on the inner margin of the maxillary mala, perhaps representing the lacinia.

MANDIBLES.

Blood-channel. A channel, either internal in the form of a duct, or excavated on the inner margin of the mandible of certain predacious larvae: e.g., GYRINIDAE, DYTISCIDAE and TELEPHORIDAE (fig. 1).

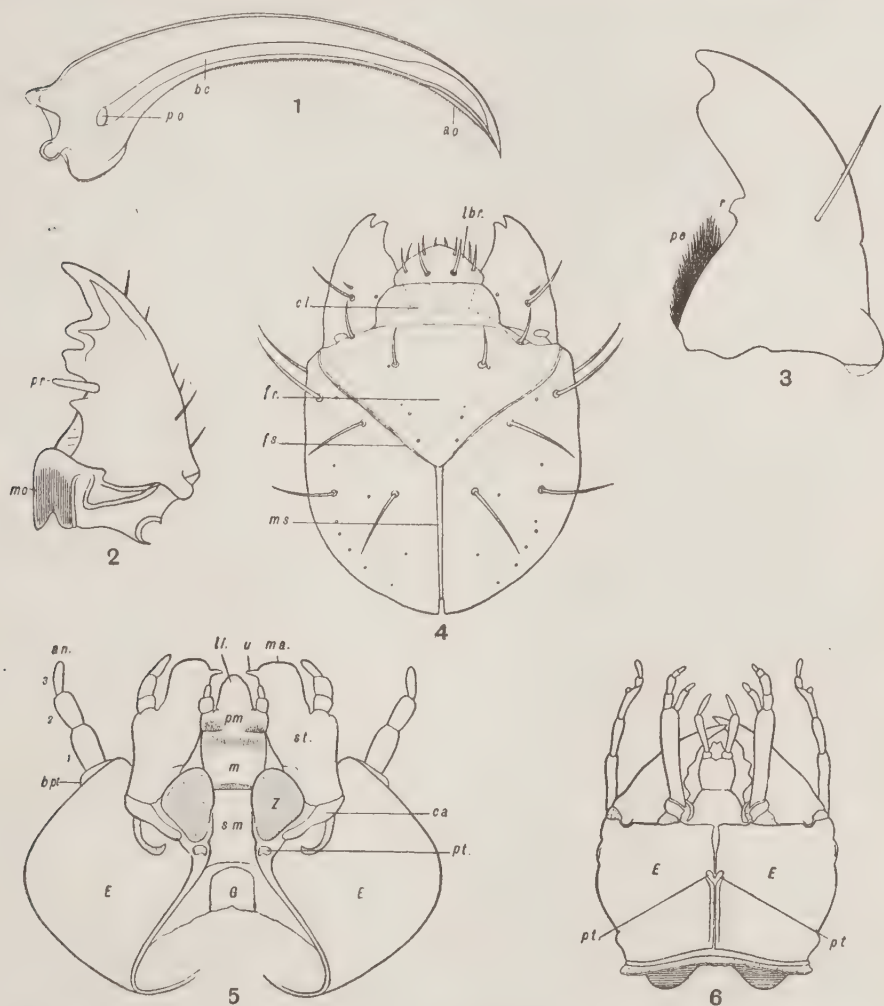


Fig. 1. Mandible of *Dytiscus*, to show blood channel: *ao*, anterior opening; *po*, posterior opening; *bc*, blood channel. 2. Mandible of *Dascillus cervinus*, L. (after Carpenter): *mo*, mola; *pr*, prostheca. 3. Mandible of *Agriotes lineatus*, L.: *pe*, penicillus; *r*, retinaculum. 4. Head of *Phyllobius urticae*, DeG., dorsal surface: *cl*, clypeus; *fr*, frons; *fs*, frontal branch of epicranial suture; *lbr*, labrum; *ms*, metopic or coronal branch of epicranial suture. 5. Head of *Pyrochroa* sp., ventral surface: *an*, antenna; *bpt*, basal process of antenna; 1, 2, 3, segments of antenna; *ca*, cardo maxillaris; *E*, *E*, epicranial plates; *G*, gula; *li*, ligula; *m*, mentum; *ma*, mala maxillae; *pm*, prementum; *pt*, posterior tentorial pit; *sm*, submentum; *st*, stipes maxillaris; *u*, uncus, perhaps lacinia maxillae; *Z*, sclerite between maxilla and labium, called Zwischenwulst by Verhoeff. 6. Head of Carabid larva, *Scarites*, ventral surface (after Snodgrass), showing maxillae attached to anterior margin of head and epicranial plates meeting at suture to form a closed cranium: *E*, *E*, epicranial plates; *pt*, *pt*, posterior tentorial pits.

Mola. A broad, more or less flattened tooth near the base of the mandible, used for grinding (Tillyard, *partim*) (fig. 2).

Penicillum. A small setiferous process or bunch of fine hairs at the base of the mandible on the inner margin (fig. 3).

Prostheca. "A slender moveably articulated tooth" (Gahan) on the inner side of the mandible (fig. 2).

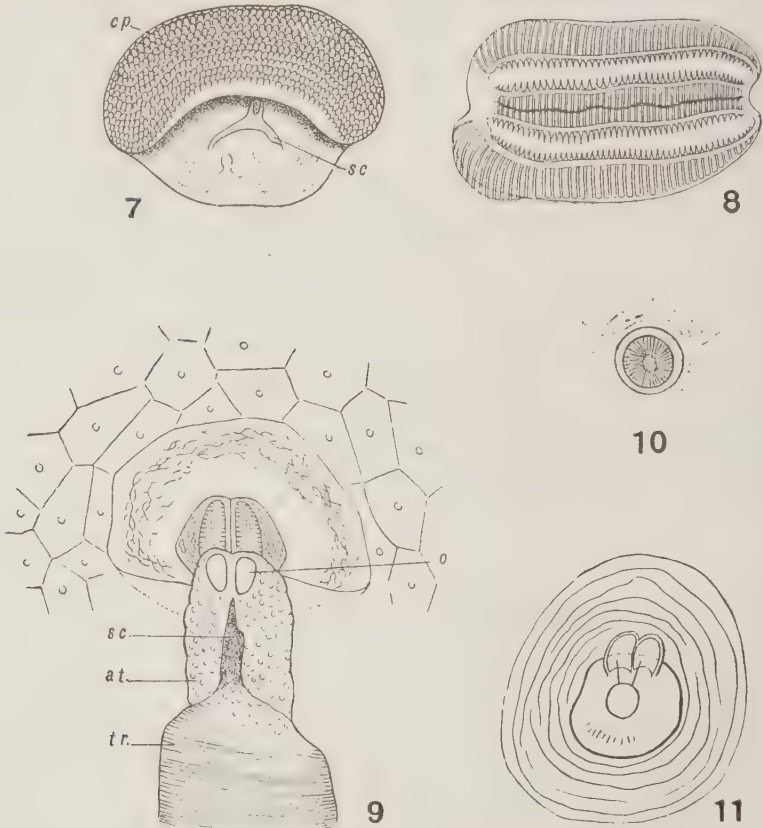


Fig. 7. Cribriform spiracle of *Geotrupes stercorarius*, L. (after Meinert): *sc*, scar of spiracle of previous instar; *cp*, cribriform plate. 8. Biforous spiracle of Elaterid larva, *Agriotes obscurus*, L., surface-view. 9. *Lampyrus noctiluca*, L., thoracic spiracle from beneath: *at*, atrium; *o*, openings into atrium from spiracle (seen by transparency); *sc*, scar (seen by transparency); *tr*, trachea. 10. Annular spiracle of a Staphylinid larva. 11. Annular-biforous spiracle of *Phyllobius pyri*, L. (thoracic).

Retinaculum. A tooth, usually pointed, situated at the middle or close to the middle of the cutting edge of the mandible (fig. 3).

SPIRACLES and RESPIRATION.

Annular Spiracle. A simple, ring-like spiracle, having a single opening and no accessory chambers (fig. 10).

Annular-biforous Spiracle. One having the principal opening round, but having two partly-developed secondary chambers (fig. 11).

Apneustic. Without functional spiracles.

Atrium. A chamber between the spiracular opening and the trachea (fig. 9).

Biforous, uniforous Spiracle. One having two, one, entrances (figs. 8, 10).

Bilabiate Spiracle. One having two lips at the entrance, which is slit-like.

Cribriform. With perforations like those of a sieve (J. B. Smith) (fig. 7).

Metapneustic System. Functional spiracles are confined to the posterior segment of the abdomen.

Openings longitudinal. Parallel to the long axis of the body.

Openings transverse. At right angles to the long axis of the body.

Peripneustic System. With first pair of thoracic and all abdominal spiracles (8) functional.

Tracheal gills. Flattened or hair-like cuticular processes, abundantly supplied with tracheae and tracheoles (Comstock, *partim*).

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A NOTE ON CERTAIN SPECIES OF THE GENUS *TIRATHABA*, WALKER (LEPID., PYRAL.).

By W. H. T. TAMS.

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(PLATE II.)

In his classification of the Pyralid subfamily GALLERIINAE (Novitates Zoologicae, xxiv, 1917), Sir George Hampson, in reviewing the genus *Tirathaba*, Walker, has created some confusion in dealing with the species *Tirathaba rufivena*, Walker.

Mr. R. W. Paine, who is working at the Instituut voor Pflanzenziekten, Buitenzorg, Java, has recently sent me, through the Imperial Bureau of Entomology, good series of two species of the genus, to the knowledge of which I am now able to make a small contribution.

In the first place, *Tirathaba ruptilinea*, Walker (described as *Lamoria ruptilinea*), is a species quite distinct from *T. rufivena*; the two species were erroneously treated as con-specific by Hampson. The material of *T. ruptilinea* in the British Museum is so poor that I have not given figures of that species here.

Until this new material arrived, *T. rufivena*, Walker, and another species, *T. mundella*, Walker, were represented in the British Museum collection by the solitary type in each case. The new series make it possible for me to give the following facts about these two species.

T. rufivena belongs to Hampson's Section I of the genus, and not, as stated by Hampson, to Section II, the male possessing the brand beyond the upper angle of the cell of the fore wing, with the consequent distortion of the end of the wing. In both sexes the hind wing is light orange-yellow, lightly shaded with fuscous towards the termen. The male has no scarlet on the fore wing, while in the female there is usually some scarlet along the upper margin of the cell and on the radial veins.

T. mundella, on the other hand, belongs to Section II. The sexes are similar, differing principally in the dark scaling through the middle of the cell longitudinally; this shading in the male takes the form of a fuscous fascia diffusely edged costad with white, extending from the wing-base nearly to the termen, and in the female the form of two fuscous dots, one at about the middle of the wing, the other at the end of the cell. There is scarlet on the fore wing in both sexes, but none between the middle of the cell and the costa. The hind wing is deep chrome in both sexes.

T. ruptilinea, which, as I have said before, is not identical with *T. rufivena*, is represented in the British Museum collection by the type female and some odd specimens of doubtful identity. The type is noticeable for two fuscous dashes in the cell, in alignment longitudinally and separated by a whitish dash. The specimen is so poor that nothing can usefully be added in the way of description until the arrival of a series similar to those which have prompted this note.

TWO NEW MOTHS WITH LARVAE INJURIOUS TO COFFEE IN UGANDA.

By W. H. T. TAMS.

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(PLATE III.)

In 1925 (Bull. Ent. Res., xv, p. 289) I described a species of *Metadrepana* (*M. andersoni*, Tams) the larvae of which were found defoliating coffee in Kenya Colony

in 1922. Figures were given of the male genitalia of three species. The species described below has for some years been known by the name *Metadrepana glauca*, Hampson, but a year or two ago I discovered, on examining some specimens sent to the Imperial Bureau of Entomology by Mr. H. Hargreaves, that these were not *M. glauca*, but a new species. Mr. G. L. R. Hancock has recently sent a good series of this new species, which is a very variable one, and I am now able to describe it.

Family DREPANIDAE.

***Metadrepana marantica*, sp. n.**

♂. Palpus light buff to cinnamon buff, streaked with drab to fuscous. Antennal shaft pale pinkish buff to light vinaceous cinnamon, sometimes shaded with wood-brown, the pectinations honey-yellow. Head Verona brown, in some examples sepia. Thorax pale pinkish buff to light pinkish cinnamon in front, remainder vinaceous fawn to fawn, in some examples drab to hair-brown. Tergum vinaceous fawn or hair-brown, light buff laterally. Pectus light buff tinged with vinaceous fawn or drab. Legs light buff shaded with vinaceous fawn or drab. Venter light buff tinged with vinaceous cinnamon or drab. Fore wing glossy, vinaceous fawn to fawn, somewhat patchily mottled with tawny olive, tints very variable; obscure antemedial and medial fasciae of tawny olive mottling; a minute indistinct blackish brown spot at about middle of discocellulars; postmedial fascia consisting of a fine fuscous line from costa at two-thirds curving apicad (concavity costad), sharply angled just above vein M1, thence bowed (concavity terminad), diverging from termen and running into inner margin at three-fourths; subterminal fascia obsolescent, frequently indicated only by a few blackish brown scales, sometimes obsolete; a few blackish brown scales scattered at intervals along costa; fringe vinaceous tawny. Hind wing colouration similar to that of fore wing; fasciae less prominent; postmedial fascia indistinct, bowed between costa and vein M3 (concavity basad), and between vein M3 and inner margin (concavity tornad); a fuscous spot between veins M3 and Cu1 half-way between end of cell and termen. Underside light pinkish cinnamon to cinnamon buff; sparse and scattered blackish brown irroration near costa, termen and inner margin in fore wing and near costa and termen in hind wing; discocellular spot and postmedial fascia on both fore and hind wings conspicuous. Expanse: 36-42 mm.

♀. Similar, but fore wing with area between antemedial and postmedial fasciae suffused with cameo-brown, the medial fascia of tawny olive mottling showing up in greater contrast than in the male; cameo-brown suffusion before the postmedial in the hind wing; both fore and hind wings with an indication of a crenulate subterminal fascia. Expanse: 40-50 mm.

Holotype ♂: UGANDA: Namenage, 20.iv.1916 (*H. Hargreaves*). Allotype ♀: UGANDA: Kampala, 16.vii.1923 (*H. Hargreaves*). Paratypes: UGANDA: 2 ♂♂, 1 ♀, Kampala, 26.viii.1912 (*H. Hargreaves*); 3 ♂♂, Kampala, 16.vii.1923 (*H. Hargreaves*); 1 ♂, 1 ♀, Bukalasa, 26.v.1926 (*H. Hargreaves*); 3 ♀♀, Company's Estate, vii.1928; 6 ♂♂, 8 ♀♀, Kampala, 16.vii.1928 (*G. L. R. Hancock*); 1 ♂, Kampala, 16.ix.1925 (*G. L. R. Hancock*); 5 ♂♂, Namakekera, 18.vii.1928 (*G. L. R. Hancock*).

The larva feeds on coffee.

LIMACODIDAE.

***Parasa hexamitobalia*, sp. n.**

♀. Palpus sepia, drab-tipped; antenna sepia. Frons Biscay green above, sepia to dark mouse-grey below; vertex Biscay green. Patagium Biscay green, edged behind with dark mouse-grey and sepia; tegula Biscay green, edged behind with dark mouse-grey; rest of thorax Biscay green, with a longitudinal medial fascia and posterior tuft of dark mouse-grey. Tergum cream buff laterally, with a broad longitudinal dorsal fascia of dark mouse-grey to fuscous; anal tuft warm buff surrounded



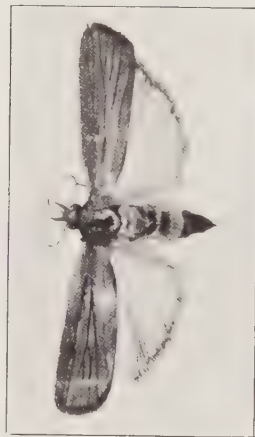
Tirathaba mundella,
Walker, ♂.



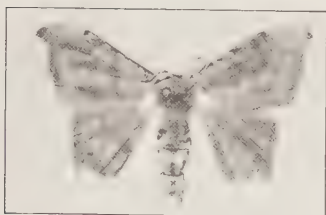
Tirathaba mundella,
Walker, ♀.



Tirathaba rufivena,
Walker, ♂.



Tirathaba rufivena,
Walker, ♀.



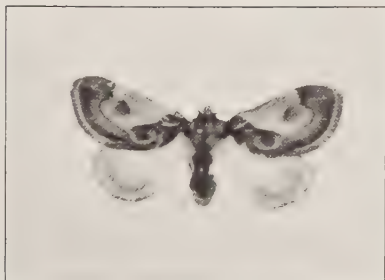
Metadrepna marantica, ♂.



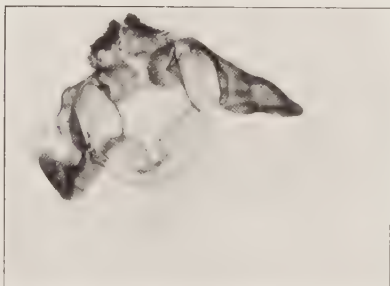
M. marantica, ♀.



M. marantica, male genital armature
with 8th ventrite folded back.



Parasa hexamitobalia, sp. n., ♀.



Metadrepna marantica, sp. n.,
female genital armature.

with drab. Pectus and legs drab to fuscous and dark mouse-grey. Venter cream buff. Fore wing drab to dark mouse-grey with the characteristic green (here Biscay green) fascia; proximal fourth of wing fuscous to dark mouse-grey, distal fourth fuscous relieved with drab along its proximal edge, which is sharply outlined with dark mouse-grey; distal edge of proximal dark patch sharply oblique tornad to lower edge of cell, then curved sharply back basad, leaving a sharp point directed terminad, further curving round along inner margin and running to join the distal dark area, the proximal edge of which runs from costa at right angles, curves deeply (concavity basad) from junction of veins $R3+R4$ to vein $Cu2$, thence inwardly oblique towards middle of inner margin, which it does not actually reach as it curves to join the edge of the proximal patch as previously stated; in the oval loop formed between the two patches lies a patch of rich oil-green to parrot-green scaling, having the appearance of a velvety spot on the Biscay green ground, and there is a similar but smaller patch beyond the sepia to fuscous discocellular streak; fringe with proximal third cream buff, distally fuscous. Hind wing cream buff, the distal third suffused with fuscous; fringe with proximal two-thirds cream buff, distally fuscous. Underside of fore wing Massicot yellow centrally, broadly surrounded with cream buff, irrorated with warm sepia along costa, degraded distally by the shadowing through of the distal dark patch of the upper side; proximal half of fringe cream buff, distal half fuscous; hind wing cream buff, irrorated with warm sepia along costa; fringe cream buff lightly edged with fuscous. Expanse: 32-38 mm.

Holotype ♀: UGANDA: Kampala, 17.vi.1917 (C. C. Gowdey); Paratypes: UGANDA: Kampala, 1 ♀, 17.vi.1917 (C. C. Gowdey), 2 ♀♀, 23.iii.1923, 1 ♀, 6.iv.1923, 1 ♀, 9.xi.1927 (H. Hargreaves); Entebbe, 2 ♀♀, 4.ix.1913, 18.iv.1914.

The larva feeds on coffee.

A NEW MOTH DAMAGING OIL-PALM IN THE BELGIAN CONGO.

By W. H. T. TAMS.

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(PLATE IV.)

Family PYRALIDAE.

Subfamily PYRAUSTINAE.

Genus *Pimelephila*, nov.

Palpus upcurved, the 2nd segment broadly and smoothly scaled in front, its distal extremity reaching the level of the vertex of the head, the 3rd segment long and acuminate (blunter in the male than in the female). Frons rounded, smoothly scaled. Tibiae with outer spurs half as long as inner. Fore wing with veins $R3+R4$ anastomosed for three-fourths of their length, $R2$ closely approximated to them, $R5$ almost straight and diverging from them; veins $M2$, $M3$, and $Cu1$ arising close together from lower angle of cell, vein $Cu2$ from cell at about five-sixths. Hind wing with vein Sc anastomosing with vein Rs to near apex; veins $M2$, $M3$, $Cu1$, and $Cu2$ disposed as in fore wing.

Type: *Pimelephila ghesquierei*, sp. n.

Pimelephila ghesquierei, sp. n.

♂. Fuscous, with a slight purplish sheen. Some light to warm buff behind the eyes. Thorax with some tawny olive scaling posteriorly. Abdomen with first segment edged with warm buff proximally, tawny olive to drab distally. Pectus and

venter warm buff to cinnamon. Legs greyish olive, femora and tibiae tinged with fuscous, tarsi olive buff. Fore wing with cinnamon streaking before antemedial fascia, particularly accentuated on costa, a prominent streak in cell, and a slighter streak below it; cinnamon along costa to just beyond postmedial fascia; antemedial fascia bowed (concavity basad), crenulate; a wedge-shaped (point basad) semi-hyaline streak in cell at two-thirds, followed by a spot of hue similar to ground colour, but darker, and filling end of cell, succeeded by a warm buff to cinnamon, longitudinal dash between veins R5 and M1; postmedial fascia from costa at two-thirds running terminad to a point just below stalk of veins R3+R4, curving (concavity terminad) to vein M2, then back towards lower angle of cell, thence oblique towards inner margin at three-fourths, with a slight bend before reaching inner margin, which it enters at right angles; it is followed and accentuated by warm buff to cinnamon, longitudinal, interneural streaks between costa and vein M2, and between cubito-anal fold and inner margin, with traces from middle of vein Cu1 to tornus. Hind wing with a dark spot on discocellulars and a bowed postmedial fascia. Under-side of fore wing similar to upper side, with some light buff along proximal two-thirds of inner margin; of hind wing the proximal two-thirds light to warm buff, on which the discocellular spot and postmedial fascia stand out prominently. Expanse: 32 mm. (30 mm. from tip to tip).

♀. Similar. Expanse: 38 mm. (35 mm. from tip to tip).

Holotype ♂: BELGIAN CONGO: Sankuru, Komi, 5.ix.1929 (*Lieut. J. Ghesquière*). Allotype ♀: BELGIAN CONGO: Sankuru, Komi, 15.ix.1929 (*Lieut. J. Ghesquière*). Paratypes: BELGIAN CONGO: Sankuru, Komi, ♂, 3.ix.1929, ♀, 15.ix.1929 (*Lieut. J. Ghesquière*); Eala, ♂, 6.xi.1927 (*R. Mayné*).

The larva of this moth damages the oil-palm, *Elaeis guineensis*.

The holotype ♂ and allotype ♀ are in the Museum du Congo Belge, while the two paratypes collected by Lieut. Ghesquière have been generously presented to the British Museum (Natural History), through the Imperial Bureau of Entomology, by Dr. H. Schouteden, Director of the Museum du Congo Belge, Tervueren, Belgium.

Congeneric with the new species here described is a species described by Sir George F. Hampson as *Pycnarmon albivittalis*. The genus *Pimelephila* differs considerably from *Pycnarmon* in the structure of the genitalia, and in the venation as regards the degree of anastomosis of vein Sc with vein Rs in the hind wing, these two veins being coincident almost to the wing apex in *Pimelephila*. In addition, the two species which I here treat as congeneric possess a facies totally different from that of any of the species of *Pycnarmon*.

(Colours from Ridgway's Color Standards and Color Nomenclature, 1912.)



Male, upper side, twice natural size.



Male, under side, twice natural size.



Small male, natural size.

Pimelephila ghesquierei, gen. et sp. n.

MOTH PESTS IN COCOA AND CONFECTIONERY.

By WINEFRED M. NOYES.

The following paper is based on work carried out on behalf of the British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades, at their laboratories in Holloway, and is now published by the courtesy of the Director of the Laboratories, Mr. T. Macara, F.I.C., and by consent of the Council of the Association.

The work was inaugurated by the Association at the request of confectionery manufacturers who had experienced loss and inconvenience through the depredations of the cocoa moth and related insects, both in the raw material and the finished goods.

Dr. L. E. Campbell, of the Association, co-operated with me throughout the work and assisted me with his technical knowledge. The photographs here reproduced were taken by him from specimens which I prepared.

I. THE MOTHS CONCERNED.

The chief pests of cocoa beans and chocolate are small moths belonging to the family PYRALIDAE (subfamily PHYCITINAE). Three species of the genus *Ephestia*, viz., *kühniella* (the Mediterranean flour moth), *elutella* (the cocoa moth) and *cautella* (the fig moth), are commonly found. These closely resemble one another in appearance, habits and duration of their life-histories. The fourth moth of the family PYRALIDAE, *Plodia interpunctella* (the Indian meal moth), differs somewhat in appearance, in the adult stage, from the other three, but little in the preceding stages, in its habits and the duration of its life-history. It is, however, more frequently found attacking nuts, such as almonds, walnuts, etc., than cocoa beans, but will thrive on these equally well.

Ephestia kühniella, Zeller.

This moth is well known all over the world for the trouble it causes in flour mills and for its ravages in farinaceous meals. It is not so commonly found attacking cocoa beans as *E. elutella* and *cautella*, but being more generally known, it may be considered first.

It was first described by Zeller³⁶ at Halle, in 1877, where it was causing much damage in a flour mill. It was thought, then, that it had come from America in grain and meal through the Mediterranean ports and had travelled thence northward through Europe. Gradually, in consequence of its widespread depredations in Southern Europe, it became known as the Mediterranean flour moth. In 1893, J. Danysz⁹ published an important paper on his own investigations and a résumé of earlier work on the subject. Having collected evidence from practical millers, Danysz gives his opinion that the pest has always been a cosmopolitan species, coming into prominence under favourable conditions. He concludes that intensity of the species development was due, probably, to the introduction and use of steam mills, with a higher maintained temperature than the old mills, rather than the importation of foreign products. In 1913, however, J. Hartley Durrant and W. W. O. Beveridge, in their "Report on the Army Biscuit Enquiry"¹¹ (p. 13), suggested that this species probably came from Central America, from Guatemala and Mexico, and that it had spread to the Southern States, reaching Europe before it had been recorded as a pest in America. They give the following description of the moth (p. 14):—

"*Ephestia kühniella* may be briefly described as a pale slaty-grey species, with an outwardly oblique, indented, dark fuscous, or blackish transverse line at one-third,

and another, strongly indented inwardly, before the end of the wing, the first preceded, and the second followed by a more or less clearly indicated pale line; between these fasciae, beyond the middle of the wing, are two blackish discal dots, one above the other, and sometimes with some dark scales above and below them; the hind wings are conspicuously whitish." The moths measure 19–22 mm. across the expanded wings and about 6–15.5 mm. from head to the tip of the abdomen.

During the day-time the moths are sluggish and remain resting in sheltered places, where they are difficult to see owing to their obscure colouring and the erect, motionless attitude which they assume. The wings are held closely pressed to the sides of the body, the head and thorax slightly elevated and the antennae reposing along the back. The females have a peculiar habit, characteristic of this species, of resting with the tips of the wings spread and flattened against the support, while between them projects the abdomen, tilted upwards, and sometimes with the ovipositor extended from the end. This position may be kept up for several days until the males appear and copulation takes place. At night the chief activity commences and egg-laying principally occurs then, each female being capable of laying 100–250 eggs, laid singly or in small clusters, and lightly fastened to the surface on which they are deposited. The eggs are ovate, and white to pale yellow in colour, about half the size of a pin's head, and just visible to the naked eye. They are laid, usually on or near the future food and are often pushed through the meshes of a sack by means of the ovipositor and laid on the cocoa beans inside. The moths appear to prefer a still, heavy atmosphere and dislike a draught, living only for 9–14 days, according to the temperature, and never taking any food.

The eggs take 7–14 days to hatch at room temperature, but when incubated at 80° F. they take, usually, about 5–9 days. The minute larva, when first hatched, is of a delicate white colour, rather hairy and more difficult to see with the naked eye than the egg itself. It immediately searches for a crack in the shell of a cocoa bean, into which it crawls, and commences to feed, spinning around itself a silken tube in which it lives until full-grown. If, however, all the cocoa beans have perfect shells, and the young larva can find no crack or crevice, it eventually dies of starvation, being unable at that age to eat through the hard outer shell. It is sometimes thought that the moth can lay eggs inside the shell of the bean. This is practically impossible, unless the bean is cracked, as the ovipositor is not sufficiently strong, but the eggs may be pushed into the smallest crevice and the tiny caterpillar will creep in and eat away the interior, filling the bean with silken webbing and excrement and showing scarcely a sign of its presence from the outside.

The full-grown larvae of *kühniella* are stout and are about 15 mm. in length and of a white or pinkish shade. Being semi-translucent the alimentary canal shows clearly through the skin as a dark stripe down the centre of the back. The young larvae feeding on chocolate and cocoa beans are often a much deeper pink than the full-grown ones. The head is chitinous and shining resin-coloured, the anal and pronotal plates are of a lighter shade than the head and there are four distinct series of black spots on either side of the larva, which are very noticeable. Each of these spots gives rise to one or two fine bristles. J. Fletcher¹³ gives a full description of the larva.

It is possible in the larvae of *Ephestia* and *Plodia interpunctella* to distinguish the sexes by means of the testes of the male, which show through the skin of the fifth abdominal segment as paired lobate bodies on either side of the dorsal vessel. The ovaries of the female take the form of two relatively minute and twisted tubes, which cannot be seen beneath the skin of the larva, but the testes of the male, in addition to their shape and size are often highly coloured, which makes them easily discernible. Both Professor E. B. Poulton²⁹ and J. Danysz¹⁰ have proved, by selecting equal numbers of larvae with and without the brown organs and keeping them separate, that only males were produced from the former and females from the latter.

When the larva is full-grown it eats its way out of the cocoa bean where it has been feeding and commences to search for a suitable crevice in which to spin a cocoon and become a pupa. At this time the quantity of webbing spun by the larvae is much in evidence. Wherever the caterpillars go they trail a silken thread behind them until the thousands of threads, crossing and recrossing, cover the sacks of beans from which they have emerged and festoon the walls of the warehouses. When larvae are fed on cocoa beans kept in jars with calico lids, the sides of the glass often become so clouded with silk that it is impossible to see inside, and the silk can be peeled off like very finely woven material. The larvae sometimes wander for as much as two days or more before they finally settle down to spin a cocoon. Within the cocoon the larva casts its old skin and becomes a shining pale brown pupa, which darkens after a few hours. The pupal stage lasts about 11-16 days at room temperature, and at 80° F. about 9-12 days.

The larval period lasts for 10-22 weeks according to season and temperature. In the summer the larvae from the eggs laid by the early moths of the season turn to pupae after approximately two or three months, but the eggs laid by the late moths of the year, *i.e.*, in September or early October, hatch and remain as larvae over the winter for a period of five or even six months before becoming pupae and emerging as moths in the following spring. Thus, there is at least one generation a year, and probably two, except in cool stores and warehouses. Moths emerge at all seasons of the year in England, but principally in June and July, and the larvae are to be seen from August to September and in large numbers in October.

J. Danysz, in 1893,⁹ on making a series of experiments with *E. kühniella*, found that the length of the life-history of this moth varied greatly in the warehouses and in the steam flour-mills. In the former, under normal temperatures, *i.e.*, unheated, he found that there were about two generations a year, one emergence of moths in May-June and another in the autumn. But in the mills, where the temperatures were noticeably higher, especially about the machinery, he found that in some parts five to six generations were produced and in others two, three and four successively, all stages of the life-history being found together throughout the year.

The range of foodstuffs other than cocoa beans and chocolate attacked by *E. kühniella* is very wide. W. G. Johnson, in "The Mediterranean Flour Moth in Europe and America"¹⁷ says that though the *Ephestia* larvae thrive best on more glutinous cereals, they infest all foods manufactured from wheat, oats, rice, Indian corn, buckwheat and grain to a limited extent. The manager of a Canadian mill found that the larvae attacked all cereals from pot barley to fine farina and milk foods in tins. He goes on to mention some very bad outbreaks of the moth in flour-mills in Canada (1889), California (1892), and New York State (1895), and the efforts on the part of the millers to keep it in check.

A summary is given in "Insect Life"³² by C. V. Riley and L. O. Howard of the history and literature of *E. kühniella*, and a description of the outbreak in the Canadian mills in August 1889. See also P. H. Bryce⁴ and J. Fletcher.¹³

Miss Ormerod, in her "Reports" 1888-1890,²⁷ notes that the flour moth was first recorded in England in 1887 and 1888, when it caused much trouble in steam mills. She mentions enquiries from mill-owners for remedies and methods of prevention, which she gives, together with a description of the larva and spreading of infestation by returned bags and loads of flour. Reference is made to Sidney Klein's paper,²² in which he describes observations on the habits of *E. kühniella* infesting over a thousand tons of flour stored in large warehouses in the East End of London and the measures undertaken to destroy it. Although the pest was practically exterminated by a small Ichneumonid parasite before the autumn, several hundred pounds' worth of damage was done.

In their "Report on the Army Biscuit Enquiry," J. Hartley Durrant and W. W. O. Beveridge¹¹ state that this moth appears to have caused trouble in Army biscuits as far back as 1801.

Wadsworth, in his "Notes on the Life History of *E. kühniella*,"³⁴ says that this species will attack all starchy foods, grain, dried vegetables, cocoa beans and nuts, also jelly cubes and chocolate.

***Ephestia elutella*, Hübner.**

This is the most generally recognized pest of cocoa and chocolate. It is well known in all cocoa-growing countries, on the plantations, whence it has spread to every place where chocolate is manufactured.

The habits of *E. elutella*, Hübner, seem to have been known in Europe since early in the last century. Chittenden, in the "Dried Currant Moth, *E. cahiritella*, Zell.,"⁷ says of *elutella* that American records contain no reference of positive injuries due to this moth, but that Réaumur's account in 1737 of a moth that injures chocolate is generally conceded to refer to this species.

The moths of *E. elutella* are small, about 15 mm. across the expanded wings and 6 mm. in length of the body. The colour varies considerably in different individuals, but is generally of a brown straw to lead-grey hue. The head and thorax are usually of the same colour as the fore wings, but the body is of a lighter and more uniform silvery grey. The fore wings are narrow and are marked by three pale straw-coloured bands, somewhat irregular and each bordered by a suffused darker line. The first band, about one-third the length of the wing distant from the body, runs nearly parallel with the outer band which borders the inner margin of the fringe. Between these two lines, starting from the lower termination of the outer band and running diagonally to the upper margin of the wing, is the third line. The hind wings are much broader than the fore wings and, though whiter, of the same silvery shade as the body.

The larvae are often a deep pink when they are small, becoming paler and more yellowish white as they approach full growth. The black spots are very conspicuous, more so than in *kühniella*, but the larvae are not so big, only measuring, as a rule, about 9–12 mm. in length. The habits and life-history of this moth closely resemble those of *kühniella* in all respects.

In 1876 *elutella* was found feeding on chicory stored in a warehouse in York.^{1, 30} Among other foodstuffs, besides cocoa and chocolate, which are attacked by this species various authorities give cotton cake,² earthnut cake,²⁰ dried fruits, figs, currants, raisins, coffee, cayenne pepper, walnuts,²⁵ flour and meal, and ships' biscuits.

***Ephestia cautella*, Walker.**

This moth was first described in 1863 by F. Walker, and later by Zeller in 1867 from two specimens from Cairo as *E. cahiritella*. It was next redescribed by Barrett, 1875, as *E. passulella* and was found feeding on dried currants and raisins (see Chittenden and Smyth.)⁸ The moth in appearance very much resembles *elutella*; it is of about the same size, but has narrower and more elongate fore wings, with the marking somewhat suffused. The colouring varies from fawn to grey, and the wings are also sometimes distinctly tinged with reddish scales. The cilia of the hind wings are marked by a strong basal line, which is not present in *elutella*. The larvae also closely resemble those of *elutella* and the habits and life-history are practically the same.

In 1882, under the synonym of *E. passulella*, W. Buckler⁵ described how he found the eggs of this moth in the Oil Cake Co.'s warehouse in 1881 and reared the young larvae on the "locust bean of commerce."

The following is a list of foodstuffs received by Dr. Chittenden⁸ in which specimens of this species were found feeding : flax seed and flax-seed meal, tonka beans, cocoa beans, linseed meal, clean or white rice, bran and cotton-seed meal. He further records damage done to cocoa shells, one mill-owner having destroyed two hundred dollars' worth of shells in 1907 which were acting as a breeding-place for moths. At the Columbian Exhibition in 1893 larvae were found to have bred in dried gall-nuts labelled "gobaishi" and exhibited by Japan. Specimens were sent from Panama of Spanish chick-peas ("garbanzos"), imported from Spain, showing injury by this species ; also specimens from Miami of larvae in seeds of *Cecropia palmata*, an evidence of a wild food-plant ; and larvae were received from China in the fruit of the jujube tree. In 1909 the records of the Bureau of Entomology at Washington showed this species, together with other insects, to be responsible for damaging rice to the extent of many thousands of dollars per annum at New Orleans. It was collected from flour, rice and cotton-seed mills, in many parts, but it does not cause so much trouble in flour-mills by choking up spouts with webbing as does *E. kuhniella*. It is recorded, however, as having a preference for the coarser and sweeter ground products of flour, and also a fondness for oily materials, such as nuts, cocoa beans and cotton seed. The author states that in 1893 it did serious damage to chocolate, and says that he was informed that the infested cocoa beans were then bought at the same price as clean material and not considered inferior, although they were filled with webbed excrement and consequently were both unwholesome and lighter in weight.

It has also been reported as being a pest of dates in Mesopotamia.⁶

***Plodia interpunctella*, Hübner.**

This moth has been known as a pest of nuts, dried fruits and cereals in Europe and America for many years and is now to be found wherever these foodstuffs are grown or used in manufacture. The larvae of this species seem to prefer substances having a greater moisture content than those attacked by *Ephestia*, but there seems little doubt that any foodstuff in which *Ephestia* can thrive will also be liable to damage by *Plodia*. Cocoa beans are not so often attacked by this moth, and it is principally in almonds, walnuts and dried fruit that it causes the most trouble.

The moths of *P. interpunctella* are of about the same size as those of *E. elutella* and *cautella*, measuring 12-15 mm. across the expanded wings and about 6 mm. in the length of the body, the size varying in different individuals. Their coloration is more distinct than that of *Ephestia*. The fore wings, from the tip of the wing for two-thirds, have a ground-colour of a reddish-ochreous shade, the inner margin of this, defined by a broad black band, borders on the pale straw-coloured basal third. The ochreous colouring of the wing tip is marked by two irregular black bands with a narrower band running diagonally between them, and the cilia, which are black, are edged at their base by another narrow black line. The head and thorax are ochreous, the eyes and antennae black, the body and hind wings silvery white, and the legs black or dark brown. The larvae are of about the same size as those of *E. elutella* and *cautella*, but vary in colour from yellowish white to pale green, and the spots, though present, are concolorous with the body, which renders them very difficult to see. The habits and life-history of this moth are practically identical with those of *Ephestia*.

This moth is mentioned by various authorities as feeding on biscuits,¹² cereals, figs,²⁸ nuts and other similar types of products. Lovett²⁴ and N. W. Kempf²¹ state that *P. interpunctella* is the moth pest of America in nuts used in confectionery, and it has recently proved a serious pest of dried fruits imported into this country.

***Corcyra cephalonica*, Stainton.**

A few specimens of this moth have been found attacking cocoa beans. It seems, however, to be rare in this material, and it is doubtful if it would ever flourish to the same

extent as *Ephestia*. Its natural foodstuff appears to be rice. It is a large moth, of about the same size as *E. kühniella*, but of a heavier build and easily distinguishable from that species. The main colour is pale fawn, with slightly darker suffused markings. The fore wings are broad compared with *Ephestia* and the hind wings, which are whitish fawn, are much fringed.

Parasites of *Ephestia*.

Only one species of the parasitic Hymenoptera has been found attacking the larvae of *Ephestia*. This is the minute Braconid, *Habrobracon hebetor*, Say. Larvae paralysed by these small insects were first observed on sacks of cocoa beans at a factory, where they were lying exposed in numbers, limp and apparently lifeless. Some of these Braconids were later obtained in cocoa beans infested by moths and a number were bred from the larvae of *E. clutella*.

A Braconid having found a larva walks over its body, examining it carefully by tapping with its antennae, the larva scarcely noticing its attentions. When the right place has been found the ovipositor is brought forward between the legs of the little insect and thrust deep into the flesh of the caterpillar. It is allowed to remain there for a fraction of a second before being withdrawn, after which a small black spot is visible on the white skin of the larva showing the position of the wound. By this means the caterpillar is paralysed, but not killed, since its heart still beats. It will remain fresh until the eggs laid by the parasite hatch and while the legless grubs feed on it, nor can it bruise or damage them, as it is incapable of any movement.

The eggs, glistening white, spindle-shaped and slightly curved, are laid on or near the body of the victim. In the laboratory they hatched in about three days, and the grubs began at once to feed from punctures in the skin of the larvae; occasionally as many as four or five were found attacking one caterpillar, which they drained until nothing but the dry, empty skin was left. The pinkish white grubs were full-grown in about eight days, and leaving the remains of the caterpillar they enveloped themselves in small white cocoons which they attached to cocoa beans or the glass sides of the jars in which they were reared. The period of pupation lasted about a month and the whole life-history, from egg to adult, covered six weeks. This seems a long time for these parasites, which usually reach maturity in about three weeks. The length of life-history in this case is probably accounted for by the fact that these Braconids were reared during the winter; in the summer months the duration would probably be much shortened.

It has been suggested that these parasites might be bred and liberated in the cocoa warehouses to destroy the cocoa moth larvae. The shortness of the life-history of the parasite in comparison with that of its host and the fact that one Braconid will destroy many larvae by paralysing them, so that, even when no eggs are laid, they never recover, are points in favour of this suggestion. But it must be remembered that the only period in the life-history of the cocoa moth in which it is attacked by the parasite is the larval stage, which is mainly spent inside the beans. There the caterpillars are inaccessible to the parasites, and it is only for the few days when they leave the beans to spin cocoons that they are liable to be attacked. Again, the number of eggs laid by the parasites is very small in proportion to the numbers laid by the moths, and so, in the long periods in which all the larvae are concealed, the Braconids would tend to die out and very few would be present when the larvae were again exposed. Consequently, although the parasites may be very beneficial when they are present in sufficient numbers at the right time, it is unlikely that satisfactory results would generally be obtained by breeding and liberating them to control the pest.

II. METHODS OF CONTROL THAT HAVE BEEN RECOMMENDED.

The infestation of cocoa beans by Pyralid moths of the genus *Ephestia* originally commences on the plantation. The moths come during the night and deposit their eggs on the beans which are exposed on the drying platforms. Thereafter, the infestation increases in the tropical stores, and again in the ship's hold in transit, where clean beans may be placed directly in contact with infested material. On arrival at the docks the cocoa is placed in bonded warehouses, which are probably already heavily infested with moth. Here it is stacked among beans which may perhaps have remained in the warehouse for two years or more and from which it may receive further infestation. In consequence of these facts it is hardly to be expected that beans arriving at a factory can be free from cocoa moth.

Badly infested cocoa is often recognisable by the excreta adhering by silken threads to cracks in the shells of the beans, through which it has been pushed by the caterpillars inside. These beans when opened will be found to contain debris, held together by silk, with the caterpillar in the middle. Larvae, at certain times of the year, may also be observed crawling on the outside of the sacks, and their cocoons can be found in the ears and seams of the bags. Recent infestation, on the other hand, is not always noticeable owing to the small size of the eggs, but after storing for a short time under favourable conditions, larvae which have developed from these eggs may be found attacking the beans.

Control in Cultivation.

A. W. Knapp, in his paper on "Insect Pests in the Cocoa Store,"²³ shows how the planter can help in the prevention of the infestation of his beans by cocoa moth. He points out that germinated beans and those with cracked and broken shells are most liable to attack. The bagging of the beans as soon as they are dry is recommended to prevent exposure to infestation and the burning of all cocoa rubbish, which provides a breeding-ground.

Cleanliness in Factories and Warehouses.

The importance of cleanliness in factories and warehouses cannot be too strongly emphasized. In the factory the rooms should be light and well ventilated, and screens of a small mesh should be fitted in the doors and windows. As a matter of convenience the warehouse is often situated near the factory, and moths flying through the open doors in summer have ready access to the packing rooms, where they infest the chocolates. To prevent this screenings would greatly help. The packing and wrapping of chocolates should be done as soon as possible after they are finished, and those which have not been packed should always be properly covered at night, when the moths are most active.

In the warehouse, the screening of windows and doors will do much to prevent the pest from spreading, and good lighting, thorough ventilation and low temperatures are also important, as moths thrive best in dark places and a still, warm atmosphere. Whitewashing of the walls and ceilings and the sweeping up of all cocoa rubbish which provides a breeding ground for moths, particularly under the duckboards on which the bags are stacked, should be regularly effected, and the constant movement of stock naturally acts as a check on the moths.

Sprays in the Warehouse.

Proprietary insecticides must be carefully considered with regard to their odour before use with such a delicate article as cocoa beans. A. W. Knapp states that the best of these, in his experience, had a formalin basis, but that he found no advantage in its use over the chemicals which he mentions.

Referring to Whympers's statement in "Cocoa and Chocolate,"³⁵ that spraying sacks of cocoa beans with formalin is very efficacious, he says that this would kill any insects on the outside of the sacks, but it "would possibly have a detrimental effect on the cocoa as formaldehyde renders proteins indigestible."

Washes for Walls, Machinery, etc.

Corrosive sublimate, 1 drachm to a gallon of water, sprayed on by means of a force pump, has been used for washing the walls of badly infested mills and warehouses, but owing to its poisonous nature it cannot be recommended.

Paraffin is useful for washing walls and ceilings, also the interior of machinery in flour mills in extreme cases.

Soda and water in strong solution is effective in killing caterpillars when in actual contact with them.

Soft lye soap and lime is also useful for washing machinery.

Wet oil emulsion. When fumigating a flour mill with hydrocyanic acid gas W. W. Froggatt¹⁴ recommends spraying the outside at the same time with a wet oil emulsion to destroy any eggs or larvae which might later cause re-infestation.

Lime washing of all walls and ceilings in mills and warehouses is of great assistance in keeping the buildings clean and free from moths. The addition of a little glue or size to help the adherence of the wash is an advantage.

Steam for Walls, Machinery, etc.

The application of live steam from the boiler, for the control of the flour moth, was tried by a miller at Miss Ormerod's suggestion, with beneficial results. A hose was used to spray the steam on the walls and machinery. Johnson states that a steam sweeper or steam introduced by a hose seemed a satisfactory method of keeping the mill clean by being capable of direction into corners, etc., and that it is better than steaming the entire mill at one time by means of fixed pipes. He recommends its use in summer when the windows and doors can be opened to ensure drying, and says that precautions must be taken that no grain, flour or manufactured products become damp during the operation. The steaming should be done regularly once a week, and since the bright parts of machinery are liable to become rusty through the process, they should be oiled before commencement.

Fumigation.

Carbon Bisulphide and Hydrocyanic Acid.

W. G. Johnson, in the "Mediterranean Flour Moth in Europe and America,"¹⁷ says that fumigation with carbon bisulphide is simple, inexpensive and most effective, but the gas is very inflammable and foul smelling. It penetrates well if used in sufficient quantities, is a powerful insecticide and will not damage manufactured products in mills. The quantities to be used depend upon the size of the building, its tightness and the degree of infestation. Johnson recommends its use in warm weather, when the insects are active, keeping the building closed from Saturday to Monday.

Carbon bisulphide is recommended by Chittenden in the "Fig Moth in Smyrna"⁸ as being probably the easiest and best method, when used in properly constructed buildings, for the fumigation of figs in Smyrna. It can be used more readily than hydrocyanic acid gas and with about the same effect. Some experiments with carbon bisulphide were tried on larvae and adults of beetles in tight flour barrels at the rate of 5 lb. per 1,000 cub. ft. air space and 10 lb. per 1,000 cub. ft. each for 12 hours and

24 hours. The author states that the "adults were killed in all four cases and the larvae in all cases except with the 5 lb. for 12 hours, when some insects crawled to the top and did not get the full effect of the gas."

The extreme inflammability and objectionable odour of carbon bisulphide render it too dangerous to be used as a fumigant in the large stores. An experiment was tried by Knapp²³ on 200 bags of cocoa in a room of 2,000 cub. ft.; 6 lb. of carbon bisulphide were used (*i.e.*, three times the amount usually recommended), "but only 50 per cent. of the caterpillars were killed."

A method is given by W. H. Johnson in "Cocoa: Its Cultivation and Preparation"¹⁹ of destroying moth larvae in cocoa beans by placing a small piece of cotton-wool, on which about one-fifth of a drachm of carbon bisulphide has been poured, inside the sack of infested beans and tightly closing it. This should kill all larvae present, but it has no effect on the eggs, and therefore more than one application will probably be necessary to kill any larvae which may later hatch from these. The writer states that carbon bisulphide has no injurious effect on the cocoa and the odour disappears when the beans are exposed to the air.

W. G. Johnson, in 1895,¹⁷ speaking of some experiments with hydrocyanic acid gas fumigation, said then that it seemed hopeful, and later, in 1899,¹⁸ that the results were very satisfactory and that he prophesied its universal use.

Hydrocyanic acid is mentioned as being successfully used in flour mills in New South Wales, all the moths, larvae and eggs being killed (W. W. Froggatt).¹⁴

The use of hydrocyanic acid for fumigating flour and rice mills is mentioned by Chittenden in the "Fig Moth in Smyrna," successful results being obtained where the mills had been made as tight as possible. Three mills infested with *E. cautella* were fumigated with hydrocyanic acid from potassium cyanide the weakest dosage being 10 oz. to 1,000 cub. ft. "Adults were all killed and no living larvae were to be found after a careful search and thorough airing of material." Experiments with sodium cyanide were also carried out, 10 oz. to 1,000 cub. ft. for 12 hours being used. All adults and larvae were killed. Owing to the difficulty of finding the eggs the effect of the cyanide upon them could not be observed.

A. W. Knapp considers that hydrocyanic acid used on a small scale would probably be very effective, but it is too poisonous to be used in large warehouses, especially if they are in populous areas.

It is stated by MacRobertson's of Melbourne, in "The Care of Sweets,"²⁶ that all their almonds are regularly fumigated by the Government with "Cynagen," which is in the main part hydrocyanic or prussic acid, and is the most deadly gas known. This gas does not in any way injure the goods fumigated.

The methods and use of hydrocyanic acid and carbon bisulphide for fumigating confectionery materials to destroy insect pests are described by N. W. Kempf, in "Control of Insect Infection in Nutmeats."²¹ The author states that "exposure to a concentration of hydrocyanic acid gas sufficient to kill eggs, larvae and moths does not cause sufficient absorption of odour to render the nuts unfit for use, nor does it cause any perceptible change in flavour." It is, however, highly dangerous and may only be handled by trained men.

Descriptions of methods for fumigating buildings are given, using a concentration equal to about 5 oz. hydrocyanic acid to 1,000 cub. ft. air space and an exposure of 36-48 hours. This is affirmed to kill all insects and also rodents without injuring nuts and confectionery raw materials in any way. For the sterilisation of finished products a method is given for the use of a vacuum in combination with gas fumigation. The material to be fumigated is placed in an airtight metal drum which is evacuated to a 28 in. mercurial vacuum before admitting the lethal gas. This ensures the penetration of the gas to every part of the material. After an exposure sufficient

to kill all insect life the fumigant is withdrawn and a vacuum is again attained, removing all trace of the active gas. Air is admitted and the door can be opened. The material is then found to be sterile, "with its flavour unimpaired," and with "no loss of weight due to shrinkage."

Hydrocyanic acid can be used in the apparatus, provided that it is in the open air, but chemically pure carbon bisulphide, which, being freed from its impurities, has lost its disagreeable odour, is recommended for indoor use. The vapour of this liquid is highly toxic to insect life, but not very poisonous to human beings. On account of its inflammability, however, it is necessary to mix it with an inert gas such as carbon dioxide, before using it. This, while not interfering with the efficiency of the fumigation, renders the gas non-inflammable and perfectly safe to handle.

By this method, if the gas used is carbon bisulphide, it is possible to sterilise the finished product after it has been packed, but not wrapped, so that re-infestation cannot occur until the package is opened by the customer.

References are given by Chittenden⁸ to papers of directions for fumigating with hydrocyanic acid (Circular 112, U.S. Bur. Ent.), and with carbon bisulphide (Farmers' Bull. no. 145, U.S. Dept. Agric.).

Sulphur.

Miss Ormerod²⁷ recommends sulphur fuming, to be repeated on successive nights in small quantities, for infested flour mills, but states that the sulphur acts badly on the gluten of the flour, spoiling it for bread-making.

W. G. Johnson¹⁷ refers to Miss Ormerod's report and says that all products should be removed from the mill before fumigating with sulphur, and all machinery, etc., carefully cleaned afterwards. He gives the proportions for fumigating as 3 lb. sulphur plus 3 oz. saltpetre to 1,000 cub. ft. of space. He states that steam plus sulphur gives satisfactory results, but that the expense of removing the stock from the mill and the time required—one week—to kill all stages of the moth, together with the deposit left by the acid, would be prohibitive. He mentions that the acid could be neutralised by ammonia and this, or some other agent, would have to be used before making flour again.

A. W. Knapp states that sulphur dioxide "was found in the laboratory to be effective in killing caterpillars. It has the disadvantage that it produces sulphurous and sulphuric acids, which would corrode any metal present in the store."

Chlorine.

Where there is danger of fire in sulphur burning, chlorine fumes are stated, in the communication of a milling firm to Miss Ormerod, to be equally effective.

Pyrethrum.

Danysz⁹ recommends a thorough fumigation of the mill with pyrethrum powder, strengthened with nicotine, when the moths are emerging from the cocoons.

Insect powder is mentioned by W. G. Johnson as having been burnt in a single mill with only slight success.

Tobacco.

Burning tobacco in mills on a large scale was not effective, but it gave fairly good results in small, tight bins and rooms.

Carbon Tetrachloride and Trichlorethylene.

Owing to their non-inflammability Knapp considers these preferable to carbon bisulphide, but since they are about half as toxic, 2 lb. to 1,000 cub. ft. would be necessary.

Formaldehyde.

Knapp states that, as this is non-poisonous and non-inflammable, it is the least harmful of various chemical insecticides. He volatilised 6 pts. of formalin in a room of 7,000 cub. ft. containing 400 bags of "grubby" cocoa, keeping the room closed for 24 hours. The treatment was unsuccessful, as a large number of insects survived, and after two days the odour was still noticeable, while the flavour of the cocoa was slightly spoiled.

Ethyl Acetate with Carbon Tetrachloride.

The use of this mixture as a fumigant is described by E. A. Back & R. T. Cotton.³ It is made by mixing 40 parts of ethyl acetate and 60 parts of carbon tetrachloride and is recommended for the fumigation of grain cars at the rate of 40-50 lb. to 1,000 cub. ft. of space. Good results were obtained in tight containers, which must be tighter than those used for carbon bisulphide, also a higher minimum temperature than carbon bisulphide is probably necessary. The authors state that the mixture must be made with pure chemicals "since odoriferous constituents will taint grain and flour."

Experiments of 24 hours' duration were carried out in tight containers to test the use of the mixture as a household fumigant on the larvae and adults of various insect pests. These were mainly Coleoptera, but *E. kühnella*, Zell., the Mediterranean flour moth, and *P. interpunctella*, Hübn., the Indian meal moth, were also present in both adult and larval forms. In the first experiment leakage occurred, but in the second all but a small percentage of the most resistant species of Coleoptera were killed. In the third experiment the kill was perfect.

It was found that 40 and 50-lb. doses of the mixture were equally efficient with the 5-lb. dose of carbon bisulphide, but not quite so efficient as the 10-lb. dose. It gave good results when used as a fumigant for threshed grain in box cars and in well-constructed, covered bins.

The purpose of adding the carbon tetrachloride, which used alone has a very indifferent killing power, is to make a non-inflammable mixture.

Inert Gas.

N. W. Kempf,²¹ showed that while the adults of moths, weevils, etc., were suffocated by a short exposure to the gas, the larvae were remarkably resistant. During a 48 hours' exposure to pure carbon dioxide the larvae remained dormant and appeared dead, but their activity recommenced immediately on the admission of fresh air. "Tests on eggs showed that they were unaffected by the gas, but that they would not hatch while exposed to it."

Vacuum.

It is stated by A. W. Knapp that truck-loads of "grubby" cocoa might be treated by vacuum in the same way as the carriages in the German State Railways. These are "run into iron cylinders from which the air is pumped whilst the contents are warmed with steam pipes." Any insects present die by the rapid evaporation of their body fluids. Thorough treatment would be necessary, as the author finds that larvae of *Ephestia* are only temporarily inconvenienced by exposure to a vacuum in the cold.

Vacuum and high air-pressure tests were carried out on *Plodia* by N. W. Kempf.²¹ The larvae and adults were killed, but the eggs were not sterilised.

Heat and Cold Treatments.

A reference to high and low temperatures as a means of control for *Ephestia* is made by W. G. Johnson. He says that a temperature of 120° F.-130° F. for 2-3

hours is fatal to larvae in manufactured products. To kill the eggs 5-6 hours is necessary, and in whole grain a higher temperature of about 150° F. may be employed for a short time. Opening the mill to the frost after steaming is recommended to kill any insects which may be about, but cold does little harm to larvae in their silken tunnels. Sterilisation of figs by dry heat at the temperature of 233° F. is mentioned in the "Fig Moth in Smyrna" (Chittenden & Smyth).⁸

As regards the temperature necessary for the destruction of the ova of *E. kühniella*, J. Hartley Durrant & W. W. O. Beveridge, in their "Report on the Army Biscuit Enquiry," 1913,¹¹ mention that eggs which were exposed to a temperature of 69° C. for 12 minutes failed to survive. They further state that "60° C. may probably be accepted as the maximum temperature above which it is unnecessary to go for the destruction of the ova, since coagulation of egg albumen takes place at 56° C."

W. H. Goodwin¹⁵ describes some experiments carried out to discover the cause of failure to kill the insect pests in treating some flour mills by heat. In two flour mills which were heated by means of radiation from steam-pipes an extremely moist atmosphere was produced. This was due to leakage, and although the temperature attained, 45° C.-47° C., was high enough to kill most of the insects present, many survived, apparently on account of the relatively high humidity, and even when the heating period was greatly lengthened they were not much affected. In similarly constructed flour mills, with slightly less radiation, excellent results had been obtained, and the extreme humidity in these mills seemed to be the only factor preventing the necessary rise "above 45° C. to the fatal temperature for most insects, 48° C.-52° C." It was found that moisture conditions are very important, that dry heat is much more economical for the destruction of insects than moist, and that a temperature of "50° C.-55° C. kills all stages of cereal insect pests if they are actually subjected to it for 1-2 hours."

A. W. Knapp²³ gives his opinion that heat is the most effective destructive agent. Some experiments done in the laboratory showed that *Ephestia* larvae died on exposure to the comparatively low temperature of 120° F. (49° C.) for 20 minutes. He states that to raise the air of a store to this temperature would be fairly easy, and where steam is available he suggests running steam-pipes round the walls, so that if at any time it was desired to sterilise the store, openings would be closed and the steam turned on. Another method of heating by means of Stanlock heaters is recommended, and "where steam is not available the hot gases produced from a coke fire may be passed direct into the store. Provided the temperature of 160° F. (71° C.) is not exceeded, the cocoa in the store is not detrimentally affected; there is only a reduction in moisture of about 1 per cent. Whilst it is not difficult to heat the air in a store, it is a much more lengthy operation to get the heat to permeate a heap of bags of cocoa. Thus a room containing 370 bags was maintained at 124° F.-140° F. for 20 hours; at the end of that time the beans inside the bags had only risen to 110° F. If, therefore, a store containing large stacks of cocoa is to be successfully treated, it will probably require two or three days' continuous heating. If the process is properly carried out every moth and caterpillar will be killed. The eggs also are rendered sterile."

The application of low temperature retards development, but Knapp says it is not possible to destroy either the eggs or caterpillars of *Ephestia* by this means.

N. W. Kempf,²¹ in dealing with *P. interpunctella*, says that owing to the alteration of the flavour of nutmeats by heat treatment, high temperatures are out of the question unless the nut is in any case intended to be roasted. The roasting of almonds and peanuts is an excellent and simple means of destroying all stages of insect life that may be present, but for pecans and walnuts some other method is necessary.

With regard to low temperatures for the storing of nutmeats, he says that in ordinary cold storage warehouses where the temperature maintained is about 32° F. the larvae and adults are killed, but the eggs are not sterilised and will still hatch when brought again under normal conditions. Although no amount of freezing will destroy the pests, cold storage is of great assistance in arresting the development of insect life.

III. EXPERIMENTS TO TEST SURVIVAL OF PESTS DURING MANUFACTURE.

The fact that chocolates which have been carefully packed in sealed tins and boxes are occasionally found to be infested with cocoa moth larvae led to the question being raised as to the possibility of the moth eggs surviving the entire process of manufacture and eventually developing in the finished product, after it has been packed. With a view to ascertaining whether the ova are capable of resisting the temperatures and conditions of manufacture, some experiments were carried out in the principal processes, with infested material.

Manufacture of Chocolate from Beans infested with Moth Eggs.

Six pounds of cocoa beans were thoroughly infested with *Ephestia clutella* moths, and after five days a great many eggs had been laid. A small quantity of these were set aside as controls. The small jars containing them were covered with calico lids and incubated at 80° F. to prove that the eggs were fertile.

The 6 lb. of infested cocoa beans were then roasted, in two batches, for 30 minutes each, the temperature at the end of the roasting being 110° C. (230° F.). From this quantity $\frac{1}{4}$ lb. was removed, placed in a sterilised jar with a calico cover, and incubated at 80° F. to permit the development of the eggs, should any of these have survived the roasting. In a similar manner from each of the succeeding stages a small amount was removed to act as a control, with the purpose of discovering up to what process, if any, the eggs were capable of surviving. The main quantity of roasted beans was then crushed and winnowed, after which the nib was passed three times through the cocoa mill. Cocoa, butter and sugar were weighed out and added to this, the whole being then put through the *mélangeur*, and finally through the refiner, the *mélangeur* and the refiner again.

The molten chocolate, when finished, was poured into sterilised 2-lb jars, each of which was filled to about two-thirds of its capacity. The chocolate was cooled and set, after which three of the jars were sealed with sterilised press caps and made airtight to ascertain if any eggs, having survived, would develop in the finished product without the admission of air. The other three jars were covered with sterilised calico lids to permit the entrance of air and give the eggs every opportunity of developing should they be still alive. These jars, together with the controls, were all incubated at 80° F.

After approximately 11 weeks from the time when the beans were first infested with moths and oviposition commenced, the six jars of set chocolate were opened, their contents examined on the surface and afterwards cracked up. In none was there any sign of insect life, either on the surface, which was in every case perfectly clean, or in any part of the broken chocolate. As an extra precaution, two jars, one sealed as before, and the other again covered with its calico lid, with their contents, were replaced in the hot room at 80° F. and the remaining jars were kept in a cupboard in the laboratory until a year later, when they were all again examined. They were then found to be as perfectly free from infestation as they had been when first opened. On both occasions the control jars of beans, removed after: (a) the roasting;

(b) nibbling; (c) grinding into mass, after passing through; (d) the mélangeur; and after (c) the refining, were also examined and compared with the jars of chocolate. In none was there any sign of insect life.

On the other hand, the four small jars of beans which had been infested with moth eggs, laid by moths obtained from the same source, and at the same time as those in the 6 lb. of beans which were made into chocolate, were found, at the end of the 11 weeks, to be heavily infested with full-grown larvae, and moths were beginning to emerge.

From this it must be concluded that the eggs were all killed by the roasting, thus accounting for the fact that none developed in the control beans removed after this process and, therefore, no eggs were alive when the other processes were commenced.

Presuming this to be the case, another experiment became necessary to prove whether eggs could survive the process of manufacture subsequent to the roasting and nibbling, *i.e.*, the stage of manufacture in which the chocolate is continuously in a molten condition until finally set as the finished product.

Molten Chocolate infested with Moth Eggs.

It was desired to prove whether eggs immersed in molten chocolate at low temperatures were capable of withstanding the immersion and developing when embedded in the chocolate after it had set. If the eggs were stirred into, or placed on the surface of molten chocolate at a temperature too low to kill them and they still failed to develop when the chocolate had been set, it would show that they were incapable of passing through the processes of manufacture in which the chocolate was in a molten state.

Some chocolate was melted down in the oven and poured into twelve small, sterilised tins in a very thin film, so that the eggs when stirred in should not be deeply embedded. In six of the tins the chocolate was cooled, and set at once, since they were to act as controls, while that in the other six was kept melted until ready to be used. A number of loose *Ephestia elutella* eggs, which had been laid over an interval of five days previous to the commencement of the experiment, were then taken, and 10 eggs were brushed on to the set chocolate surface of each of the six control tins. These tins were each placed at the bottom of a sterilised glass jar, which was covered with a calico lid, to permit ventilation and to exclude any stray moths or larvae. The remaining six tins were cooled one at a time, and the temperature of the chocolate taken with a thermometer. At between 35° C.-30° C. 10 eggs were stirred into the film of chocolate in each tin, which was then immediately surrounded with cold water to make the chocolate set quickly; they were at once placed, like the others, each at the bottom of a sterilised jar and covered in the same way. Of these twelve jars, three controls and three with the eggs stirred into the chocolate, were placed in a dark cupboard in the laboratory, at room temperature; the remaining jars were incubated at 80° F.

It was still thought possible that whereas the eggs in the last experiment might not be able to hatch owing to the fact of their being surrounded with chocolate, eggs might be able to develop if they had been merely dropped on to the surface of melted chocolate and allowed to settle by their own weight.

Accordingly, a thin film of melted chocolate was poured into eight small sterilised tins, as before, and four of these were at once cooled and set. On to the surface of each of these controls 10 eggs were brushed, and each tin was placed at the bottom of a sterilised glass jar and covered with a calico lid. The chocolate in the other tins was allowed to cool to between 35° C.-30° C. when 10 eggs were shaken on to the surface of each film, but not stirred in; the chocolate was then immediately set.

These tins were also placed at the bottom of glass jars. Two of the controls and two of the experimental jars were incubated at 80° F., and the remaining four, two of each, were placed in the laboratory cupboard.

Six months later these jars were all opened and the chocolate films in each tin carefully examined. All the experimental films of the first series, both those which had been incubated and those which were kept at room temperature, were found to be perfectly free from any sign of insect infestation. In both sets of controls, however, *Ephestia* larvae were present and the surface of the chocolate was much eaten.

Similar results were obtained with the second series, which was examined after the same length of time, all those chocolate films on to which eggs had been shaken when they were in a molten condition being absolutely free from insect life, while the controls which had been infested with eggs after the chocolate had set were much eaten by *Ephestia* larvae.

It must be concluded from these results that the eggs of cocoa moths are incapable of surviving immersion in or deposition on the surface of molten chocolate, and it is probable that they are destroyed by means of the oily chocolate which, in closing the pores of the egg-shell, prevents the respiration of the ova.

It will be seen from these two experiments that it is quite impossible for moth eggs to pass through the process of chocolate manufacture, and the only operation, from the roasting until the chocolate is finished, in which infestation with eggs might occur is the "nibbling." This, however, is unimportant, since as a process, it comes, between two stages of manufacture in which all insect life is exterminated. Thus, it is composed of cocoa beans which have been sterilised by roasting, and should it become, itself, infested all life will be destroyed immediately the grinding commences and it becomes "mass." Consequently, the two places in which the manufacturer must guard against the infestation of his material by cocoa moth are in the cocoa warehouse and in the packing rooms where the finished cocoa is exposed.

Roasting of Cocoa Beans infested with Larvae and Pupae.

In order to ascertain whether the larval and pupal stages of the cocoa moth were killed by the process of roasting, 3 lb. of infested beans were roasted for 40 minutes, the temperature of the beans being 86° C.—100° C. (187° F.—212° F.) at the end of the experiment. These beans were put aside and carefully screened from moths until the next day, when they were all examined. Any bean which showed the slightest crack or crevice in the shell was cut open and examined inside. A number of *Ephestia* larvae were found which were so dry that they broke in pieces when the beans were opened, but no pupae were found. Some larvae and adults of the beetle, *Plinus tectus*, were also present, and these were all found to be dried and shrivelled.

Those beans with perfectly whole shells were put together in five sterilised jars, one of which had a screw lid and the others were covered with calico. They were then incubated to make certain that no insect life had survived in them.

After approximately six months all these jars of beans were opened and again carefully examined, the beans being broken up. In no case was there any indication of the presence of living cocoa moth in any stage of its life-history.

This experiment showed that the larvae of the cocoa moth are destroyed by roasting and, in later experiments in heat treatment, it was found that the pupae would also be destroyed by this process.

Length of Life of *Ephestia* Larvae in Closed Tins and Boxes.

A box of chocolates was received by the laboratory from a manufacturing firm with the statement that the chocolates had been put down two years previously and that

when they were opened, although the sealed and waxed wrapper appeared perfectly intact, caterpillars were found feeding on the chocolates and had even penetrated the tinfoil in which they were wrapped. The question was asked whether these larvae had developed from eggs laid during the packing of the chocolates, two years ago, when the box was last open, and if not, how was their presence to be accounted for?

When the cardboard box was emptied and examined in the laboratory a small hole was found in one corner at the bottom, which had probably been caused by rubbing on a shelf. As the larvae in the chocolates were found to be almost full-grown and no pupae were present, nor any moths, it was concluded that this was the first generation, since the life-cycle of *Ephesia* at room temperature does not last at the most more than a year. Had it been the second generation, from infestation before packing, empty pupal cases and dead moths must have been present. It is probable that the larvae entered through the small hole when recently hatched from eggs laid that summer by stray moths in exposed material near by.

To find out how long these larvae could continue to live if sealed up in an airtight container the chocolates, removed from the box referred to, were placed in a glass jar with the larvae still feeding on them and the jar was closed up with a press cap. It was thought best to keep the chocolates at room temperature, as they had been before, so the jar was placed in a cupboard in the laboratory. This was in October, and all the larvae which could be seen through the glass seemed for some time to remain quite healthy.

In the following March some larvae were seen spinning cocoons, and in April the first *E. clutella* moth emerged. After this four others were seen to emerge, the last on 26th May. In January, the next year, 14 months after the closing of the jar, it was opened, the tinfoil taken off the chocolates and all of them examined. Not a single living caterpillar was found; many were dead at the bottom of the jar, black and shrivelled; some having tried to spin up had failed and were dead under the web they had commenced. No living moths were present and all life seemed to have died out since the summer.

In November, the same year that the jar mentioned above was closed, two small tins in the hot room containing chocolates were found to have become infested by stray larvae, bred in some chocolate rubbish. These had crept in under the rims of the ill-fitting lids.

An infested chocolate was removed from each of these tins and placed separately in a small jar. To ensure sufficient infestation in the tins, each of which contained two chocolates, three nearly full-grown *E. clutella* larvae were added to those few which were already there in the chocolates, and into the two small jars, which held only one chocolate each, two larvae were placed.

The first tin was left exactly as it was found, with the lid on, but it was placed inside a glass jar with a calico cover to prevent the escape of any larvae or moths from inside and the entrance of any stray moths from without. The second tin was closed and sealed with sealing wax around the lid and the joins of the tin to make it quite airtight, and the two small jars were closed with press caps. These were all replaced in the hot room.

The two tins were left unopened until 13 months later when, on opening, the chocolates and paper were found to be much webbed over, but the larvae in the first were all dead and shrivelled. In the second, which had been sealed, two moths were found dead and one larva which had spun a cocoon, but had died before transforming; beyond these no more larvae were found and in neither tin were there any insects alive. The small jars were also left unopened for 13 months, but since they

were glass it was possible to watch the larvae in them. The two caterpillars that were put into the first of these died less than a month after the jar was closed, and when it was opened three other larvae were found dead and shrivelled inside the chocolate. Of those in the second jar, one began to spin a cocoon a fortnight after it was closed and another about three months later. On 1st February one moth was seen to have emerged and died, but the other pupa was still in its cocoon. When this jar was finally opened and the chocolate examined only two dead moths were found and no insects in any form were alive.

From these experiments it seems probable that, owing to lack of ventilation and of space, the propagation of moths in airtight boxes and tins of chocolate will not extend beyond one generation, though probably in cardboard packages the penetration of air would be the determining factor.

IV. EXPERIMENTAL TESTS OF CONTROL MEASURES.

Treatment by Heat.

It has been proved by experiment that the eggs of *Ephestia* are incapable of surviving the process of chocolate manufacture, and it is obvious that infestation of chocolate while it is in a molten state is impossible. A moth endeavouring to settle on the melted surface would inevitably adhere to it and be unable to escape, and eggs which might otherwise reach the chocolate would at once become coated and prevented from hatching, even supposing the temperatures to be insufficient to kill them. Thus, if we eliminate the actual processes of manufacture, the two periods in which preventive measures must be taken against cocoa-moth infestation are: When the beans arrive at the factory and are stored in the warehouse and, after manufacture, in the finishing and packing rooms, where the finished chocolate may become infested by stray moths. Of these, the first is the more important, as the beans stored in the warehouse are the source of all infestation in the factory, and therefore, if they could be sterilised on arrival and afterwards stacked in a clean store, in which every care to guard against re-infestation were taken, the present trouble with moth would be eliminated to a very great extent, if not completely so, in time.

There are two possibilities for the treatment of cocoa beans to destroy insect life, *viz.*, fumigation and heat treatment. The first of these entails the employment of some gas, such as hydrocyanic acid, carbon bisulphide, or a mixture of vapours such as ethyl acetate in combination with carbon tetrachloride. There are, however, certain objections to the use of these substances in the difficulty and danger of handling them, while there is also the risk of tainting the beans. Cocoa, owing to its oily nature, is very susceptible to foreign odours, which it readily absorbs, and the flavour is easily spoiled. Then there is the difficulty of ensuring effective penetration by the gas when the beans are stacked in large quantities, and the necessity of providing a gastight chamber. All these features must be taken into account when fumigation is considered.

Heat treatment, on the other hand, is not dangerous to use, does not require expert labour and is easily carried out. It is clean and has no harmful effect on the beans, for Knapp states that "provided the temperature of 160° F. (71° C.) is not exceeded the cocoa is not detrimentally affected, there is only a reduction in moisture of about 1 per cent." The penetration of the beans by sufficient heat to kill can be assured either by exposing them for several days to suitable temperatures in hot rooms or by passing them loose through a machine at higher temperatures and in a very much shorter time. It will be seen that sterilisation of beans by heat is, in comparison with fumigation, a safer and more simple method, and if care is taken to allow sufficient time in treatment, the cocoa moth in all its stages should be completely destroyed.

In order to discover what would be the most suitable temperature and period of time to employ in the treatment of cocoa beans by heat the following experiments on the larvae, pupae and eggs of *Ephestia* were carried out.

Temperatures and Time required to destroy the Larvae when directly exposed to the Heat.

Since very little seemed to be known of the capabilities of larvae for resisting heat treatment at various temperatures, five experiments were made with *E. elutella* larvae, in which they were actually exposed in open petri dishes to the constant temperatures of 50° C., 55° C., 60° C., 65° C. and 70° C. for increasing lengths of time.

A small electric oven was used, a thermometer being inserted through the top so that the air temperature of the interior could be observed without opening the door. In each experiment the larvae were put in one half of a glass petri dish which was then placed in the oven with a cork sheet separating it from the perforated iron tray. This served the purpose of insulating the dish from the higher temperature of the metal, and the larvae were thus actually exposed, so far as was possible, only to the air temperature of the oven. At every five minutes from the beginning of the experiment until 50 minutes had expired a few larvae were removed. Each batch was then placed in a small tube with some broken cocoa bean and incubated at 80° F. until the next day. All five experiments were carried out in exactly the same manner.

It was found that at 50° C. the larvae were killed in 20 minutes, at 55° C., they died a little after 15 minutes, at 60° C. in 5-10 minutes, and at 65° C. and 70° C. they died in less than 5 minutes.

These results show that *Ephestia* larvae are easily destroyed by exposing them to moderately high temperatures.

Temperatures and Time required to destroy Larvae in Cocoa Beans.

Having found the time required at certain temperatures to destroy larvae actually exposed to the heat, the next step was to discover what time at the same air temperature was necessary to destroy them when they were inside the cocoa beans. For this purpose a short experiment was carried out.

Six tests were made with the oven at a temperature of 50° C. In each test 12 cocoa beans showing evidence of infestation by larvae were put in half a glass petri dish. This was placed in the oven, a cork sheet insulating it from the iron tray on which it rested, and heated for the required length of time. One exposure was made for 25 minutes, one for 30 minutes, and two each for 35 and 40 minutes. It was discovered that as the temperature of the beans gradually rose many of the larvae crawled out.

At 55° C. ten tests were carried out on infested beans in the same way as at 50° C. Here one test each was made for 10, 15, and 20 minutes, two for 25, three for 30 minutes and two for 35.

At 60° C. eight tests were made, the exposure being the same as at 55° C., but two tests were made for 30 minutes, instead of three, and only one was made for 35 minutes instead of two.

After heating, the beans in each test were incubated until the following day to give those larvae which had not been killed an opportunity to recover. They were then opened and carefully examined, all the larvae which were found in them and those which had crawled out being counted. After 40 minutes' exposure at 50° C. it was found that 1.7 per cent. larvae had survived in the beans; these, however, died a few days later. At 55° C., 17.9 per cent. larvae survived after 30 minutes, but none survived after 35 minutes.

At 60° C., after 25 minutes' exposure, 15.3 per cent. larvae survived, but after 30 minutes all were destroyed.

RESULTS OF HEATING EXPERIMENTS ON *Ephestia* LARVAE IN COCOA BEANS ON PETRI DISH IN OVEN.

TABLE IA.

Temperature desired, 50° C.

Time in Minutes.	Average Air Temp. of Oven °C.	Max. Temp. reached.*		No. Dead.	No. Alive.	Per cent. Surviving.
		Interior of Bean °C.	Petri Dish °C.			
25	50.9	47	49	—	22	100
30	51.4	48	49	18	3	14.3
35	50.8	48	49	18	—	0
35	50.6	48	49	25	19	43.2
40	50.7	49	50	24	—	0
40	50.2	49	50	59	1	1.7

TABLE IB.

Temperature desired, 55° C.

10	56.7	38	52	—	20	100
15	56.2	48	53	1	12	92.3
20	56.3	51	53	33	2	5.7
25	55.3	52	54	29	—	0
25	55.5	52	54	3	6	66
30	52.5	53	55	26	—	0
30	55.5	53	55	23	5	17.9
30	56	53	55	50	—	0
35	55.5	53	55	16	—	0
35	55.9	53	55	29	—	0

TABLE IC.

Temperature desired, 60° C.

10	60	48	52	—	39	100
15	60.1	53	54	10	18	64.3
20	59.6	55	58	50	—	0
25	60.1	55	58	31	—	0
25	59.8	55	58	22	4	15.3
30	60.4	56	59	31	—	0
30	60	56	59	28	—	0
35	60.3	56	59	42	—	0

* Temperature taken by means of a thermo-couple pyrometer.

To destroy larvae inside cocoa beans, therefore, almost twice the length of time is necessary that is required when they are actually exposed to the same air temperature on a petri dish. This, however, will always depend upon the degree to which the beans have been eaten by the larvae, the heat naturally requiring a longer time to penetrate firm and slightly eaten beans than those which have been much eaten and practically reduced to powder inside.

After the foregoing experiment was carried out, a thermo-couple pyrometer was obtained with which it has been possible to find the temperature of the interior of the cocoa beans during the time in which they were in the oven. The needle of the thermo-couple was pushed into a bean resting, as in the tests, on a petri dish. At 5-minute intervals from the time the needle was inserted, readings were taken on the dial and it was found that after 40 minutes' exposure to 50° C. air temperature the

centre of the bean had only risen to 48° C. At 55° C. after 30 minutes, 53° C. was reached in the bean, and there was no further rise in temperature after 35 minutes. At 60° C., 56° C. was reached inside the bean after 30 minutes, and after another 5-minutes the temperature still remained the same.

The results of these experiments show the necessity of allowing sufficient time for the heat to penetrate the beans in which the larvae are concealed, in addition to the time that is actually required to kill them. The temperature of the bean rises quickly in the first 15 minutes, after which it rises more slowly until the air temperature of the oven is reached. It was found that on an average, after 20 minutes' heating at the constant temperature of 50° C., 55° C., and 60° C., the interior of the bean was still 4° C. below the air temperature of the oven.

Heat Treatment of Pupae.

The pupae of *E. clutella* were subjected to heat treatment in open petri dishes in the oven in the same way as the larvae had been. They were exposed for the same periods of time at the same temperatures, and it was found that at 50° C. moths succeeded in emerging from pupae heated for 10 minutes, one moth even emerging after 20 minutes' exposure. At 55° C. and 60° C. moths only emerged from pupae exposed for 5 minutes, and at 65° C. and 70° C. no pupae survived after 5 minutes' treatment. In every case they were incubated and ample time was allowed for the moths to emerge. There is nothing to indicate from the exterior of an infested bean whether a pupa or only a larva is inside, and a bean once opened would be useless in this experiment. It was therefore impossible to ascertain what time at the given temperatures would be required to destroy pupae inside beans; but as it has been proved that they are readily killed by the same temperatures and exposures as the larvae when heated in petri dishes, it may be presumed that the same treatment would be successful with both larvae and pupae when actually inside the cocoa beans.

Heating of Beans by Rotation in a Cylinder inside an Oven.

An attempt was made to discover if beans could be efficiently sterilised by rotating them in a cylinder in a small electric oven. In this way by keeping the beans moving, heat penetration, causing a total destruction of insect life, could be assured in the shortest space of time at given temperatures. Those exposures which had proved the most successful in the previous experiment of heating larvae-infested beans in petri dishes were chosen for these tests.

A small copper cylinder was constructed to fit inside an electric oven and made to turn horizontally on an axle. It was fitted at each end with lids which could be unscrewed when necessary, and it also had an aperture in the side with a short neck through which it could be filled without removing it from the oven. This aperture was closed with a cork when the apparatus was in use. Rotation of the cylinder was effected by means of a motor outside the oven.

At 50° C. four tests of 40 minutes' duration were made with infested cocoa beans. In two of these, Nos. 1 and 7, 12 beans only were treated in each, and in these it was found after treatment that 100 per cent. of the insects present had been destroyed. In Nos. 3 and 5, $\frac{1}{2}$ lb. of infested beans were rotated in the cylinder. This quantity seems to have been rather too much for its capacity, since in No. 3, 66 per cent. survived, indicating that the beans had not turned over properly owing to the lack of baffles in the interior for mixing them. The result was that, as the cylinder revolved, the beans lay in a mass on its lowest surface, thus preventing the heat from penetrating every bean equally and thoroughly.

Control tests were made at the same time as the beans were rotating in the cylinder. Twelve infested beans were selected and placed in a petri dish at the

bottom of the oven during the experiment. The dish rested on a cork sheet and the beans in it were heated for exactly the same time as those in the cylinder. After heating it was found that all insects in these had been destroyed.

At 55° C. four tests were made for 35 minutes each. In three of these (Nos. 1, 5 and 7) all the insects were destroyed after heating, but in No. 3, one of those in which $\frac{1}{2}$ lb. of infested beans was treated, 33 per cent. survived. This was due to the quantity being too great for the cylinder, as occurred in the preceding experiment. In the control tests no insects survived the heating.

At 60° C. one test was made for 20 minutes and one for 25, in which all life was destroyed after heating, and of the four tests which were heated for 30 minutes, three were successful. In No. 5, in which $\frac{1}{2}$ lb. of beans was again heated, 45 per cent. survived. All insect life was destroyed in the control tests.

At 56° C. tests of 10, 15, 20 and 25 minutes were made. In these 12 beans only were treated in each test and only in No. 1 for 10 minutes did any insects survive. Here, however, 85.5 per cent. insects were found alive, which indicates, in spite of the results of the other two tests for that time, that it is too short a period to be thoroughly effective.

At 70° C. three tests were made for 15 minutes' duration and three for 20 minutes', in all of which the insects present were killed.

In Table II, thermo-couple temperatures are given for the interior of the beans and the petri dish, in each of the controls.

HEATING OF INFESTED COCOA BEANS IN ROTATING CYLINDER.

TABLE IIA.

Temperature desired, 50° C.

Time in Minutes.	Average. Air Temp. of Oven ° C.	*Max. Temp. reached.		No. Dead.	No. Alive.	Per cent. Surviving.
		Interior of Bean ° C.	Petri Dish ° C.			
40	50.4	—	—	11	—	0
40	50.8	48	50	15	—	0 (control).
40	50.8	—	—	4	8	†66 ($\frac{1}{2}$ lb. of beans).
40	50	48	50	2	—	0 (control).
40	50	—	—	2	—	†0 ($\frac{1}{2}$ lb. of beans).
40	50.4	48	50	25	—	0 (control).
40	50.4	—	—	19	—	0

TABLE IIB.

Temperature desired, 55° C.

35	55.5	—	—	26	—	0
35	54.9	53	55	3	—	0 (control).
35	54.9	—	—	8	4	†33 ($\frac{1}{2}$ lb. of beans).
35	55.4	53	55	2	—	0 (control).
35	55.4	—	—	2	—	†0 ($\frac{1}{2}$ lb. of beans).
35	54.5	53	55	20	—	0 (control).
35	54.5	—	—	27	—	0

TABLE IIC.

Temperature desired, 60° C.

Time in Minutes.	Average. Air Temp. of Oven ° C.	*Max. Temp. reached.		No. Dead.	No. Alive.	Per cent. Surviving.
		Interior of Bean ° C.	Petri Dish ° C.			
20	60.1	—	—	5	—	0
25	60.2	—	—	7	—	0
30	60.3	—	—	3	—	0
30	60	56	59	6	—	0 (control).
30	60	—	—	11	5	†45 (½ lb. of beans).
30	60	—	—	1	—	†0 (½ lb. of beans).
30	60.1	56	59	19	—	0 (control).
30	60.1	—	—	12	—	0

TABLE IIB.

Temperature desired, 65° C.

10	64.9	—	—	1	7	87.5
10	64.5	—	—	5	—	0
10	63.7	—	—	4	—	0
15	65.2	—	—	20	—	0
15	66.1	—	—	4	—	0
20	65.3	—	—	8	—	0
20	64.5	—	—	14	—	0
25	64.3	—	—	18	—	0

TABLE IIE.

Temperature desired, 70° C.

15	70	—	—	3	—	0
15	70.1	—	—	6	—	0
15	69	—	—	8	—	0
20	70.1	—	—	3	—	0
20	70.2	—	—	1	—	0
20	70	—	—	4	—	0

* Temperature taken by means of a thermo-couple pyrometer.

† ½ lb. infested beans heated in cylinder. In all other tests 12 beans only were heated.

Control tests were carried out by heating 12 beans in petri dishes on bottom of oven as usual.

This method proved satisfactory for the destruction of larvae, but at the time of experimenting no pupae or moths were obtainable and, in consequence, the effect of the treatment on the pupae and eggs could not be ascertained. Since it has been found, however, that the pupae are readily destroyed by the same temperatures and exposures as the larvae, they would be easily killed by heat treatment in the cylinder. It also seems probable that eggs laid on the surface of beans would be more easily destroyed by this method than when they are simply heated on the beans placed in open petri dishes in the oven. The cylinder is already hot when the beans are put into it, and by the movement they are at once brought into contact with the hot metal and kept constantly knocking against each other and against the sides of the container. The pupae, which are more often in cocoons on the outside of the beans than inside them, and the eggs would therefore be heated more quickly than is possible in a petri dish, which is cold at the commencement of the experiment, and both forms of life would be liable to be crushed between the moving beans.

Sterilisation of Cocoa Moth Eggs by Heat.

Heating experiments were carried out on the eggs of *Ephestia*: (A) loose, on petri dishes; (B) laid on cocoa beans, to discover what lengths of time at various air temperatures are necessary to ensure their complete destruction.

Throughout these experiments the eggs of *E. elutella*, the cocoa moth, were used, as the temperatures and exposures necessary to destroy these will, it may be assumed, also destroy those of *Plodia* and the other *Ephestia* which damage cocoa beans.

(A). The eggs used in each series of this experiment were in no case more than three days old. For heating, a number of eggs were placed loose in several open petri dishes, which were then exposed to a constant temperature in the oven, one dish being removed every 5 minutes up to 30 minutes. After treatment, the eggs were incubated and time sufficient for them to hatch allowed, the results shown in Table III being obtained.

(B). In this experiment the eggs were heated on the cocoa beans to which they had been attached by the moths. Care was taken to crack the shell of every bean on which eggs were laid, as it has been found that the young larvae when first hatched are incapable of eating through the hard shell and if unable to get inside by other means they die of starvation. Consequently, though they might hatch after treatment, they could have no chance of developing, and their non-development might be attributed to the effect of the heat. In each test 6 beans on which the eggs had been laid were heated in an open petri dish. So far as it was possible to count them, some having been thrust into the cracks in the beans and under the edges of the shells, approximately 20 eggs were used in each test, the number being made up by the addition of a few loose ones where it was insufficient. At the most, the eggs heated in these tests had never been laid more than seven days previously. To make certain of their capability for hatching, controls were made on every occasion on which eggs were heated, the eggs used in the controls always being part of the same batch as those used in the tests.

TABLE III.
EFFECT OF HEAT TREATMENT ON THE EGGS OF *Ephestia*.
Temperature in Dish taken by Thermo-couple Pyrometer.

Time of Heating in Mins.	Air Temperature of Oven.									
	50° C.		55° C.		60° C.		65° C.		70° C.	
	Temp. in Dish in ° C.	Result.	Temp. in Dish in ° C.	Result.	Temp. in Dish in ° C.	Result.	Temp. in Dish in ° C.	Result.	Temp. in Dish in ° C.	Result.
5	42	Hatched*	44	Hatched	50	Hatched	58	†	62	‡
10	47	„	52	„	52	„	59	Sterilised	64	Sterilised
15	48	„	53	„	54	Sterilised	59	„	69	„
20	49	„	53	Sterilised	58	„	62	„	70	„
25	49	Sterilised†	54	„	58	„	63	„	70	„
30	49	„	55	„	59	„	63	„	70	„

* The eggs hatched out after incubation at 80° F. for several days.

† The eggs were brown and collapsed and failed to hatch out after incubation.

‡ Eggs removed after five minutes failed to hatch.

These tests were made in sets of three, six or nine dishes, all of which were put in the oven together. The shortest exposure allowed at any temperature was 10 minutes, and the longest 55 minutes. Separate dishes were removed at intervals of 5 or 10 minutes, according to the length of time it had been decided to give. Immediately on their removal from the oven, after heating, the beans, with the eggs attached, from each test were placed in sterilised jars with calico covers (also sterilised) and incubated at 80° F., together with the controls made at the same time. The incubation was continued generally until larvae had developed or from six to eight months in other cases. Thus the eggs had every opportunity of developing should they have survived the treatment.

At regular intervals all these jars of beans were carefully examined, and the tests were retained until the life-cycle of the eggs which survived was completed, the larvae having become moths. Percentages of these eggs, however, were not taken, as the fact of any having survived was considered sufficient proof of the exposure at the temperature in question being unsatisfactory.

The untreated eggs in the control jars in every case developed to maturity, which shows that those used in the heating tests were all perfectly capable of development under favourable conditions.

The results of this experiment are shown in full in Table IV.

The difference in the time required to destroy loose eggs heated on an open petri dish and those which are attached to the cocoa beans is due in part to the fact that the petri dish heats up more quickly than the exterior of the bean in the first 5–10 minutes. Where the eggs have been found to hatch after long exposures to the heat it is probable that they may have been thrust deep into the cracks of the beans and so have been protected longer than those laid on the outside. As the moths naturally prefer to lay their eggs in crevices in the beans, which give them a better place of attachment and offer the larvae ready access to the food material when they hatch, time must be allowed in heat treatment to destroy both the eggs on the outside and those which are pushed into the cracks. It was found that the capability of eggs for resisting heat treatment varied considerably and was not necessarily dependent upon their age. Those laid on the same dates, but by different moths, and given exactly the same treatment, survived in some cases, but completely failed in others. It does not seem possible to account for this discrepancy in any way otherwise than by ascribing it to individual differences.

Owing to eggs having survived treatment for 40 and 50 minutes, the temperature of 50° C. seems too low to recommend for the purpose of sterilising beans unless the heating is continued for longer periods.

The series of tests made at 55° C. and 60° C. showed that no eggs heated at these temperatures survived exposures of 40 minutes and upwards. To prove this, further tests, not shown in the table, were made with exposures increasing up to an hour and an hour and a half, and in these all the eggs were destroyed.

At the temperature of 65° C. no eggs survived heating after 25 minutes and upwards, but since, at 70° C., after exposures of 25 minutes eggs survived, it is unsafe to say that this is not also possible at 65° C. In this case the minimum exposure necessary to ensure the total destruction of eggs at these temperatures would be 30 minutes. Here also the tests were continued beyond those shown in the tables, but no eggs survived after those last indicated.

Conclusion for Heat Treatment.

The times and temperatures given refer only to ideal conditions, namely, the subjection of a few isolated beans to relatively large volumes of hot air.

In actual practice, however, the rate of penetration of heat through sacks of beans will have to be taken into account.

THE DESTRUCTION OF COCOA MOTH ON BEANS BY HEAT TREATMENT.

TABLE IVa.

Temperature desired, 50° C.

Experiment No.			Age of Eggs when heated, in Days.	Heating, Time in Minutes.	Average Air Temperature of Oven in ° C.	Maximum Temperature reached on Surface of Bean, ° C.	Result.
1	...	...	3	20	50	48	Hatched
2	...	...	2	20	50	48	„
3	...	...	3	20	50·6	48	„
4	...	...	3	20	49·7	48	„
5	...	...	5	30	50	49	„
6	...	...	2	30	50	49	„
7	...	...	3	30	50·4	49	„
8	...	...	2	30	50·2	49	Sterilised
9	...	...	5	35	49·7	50	„
10	...	...	3	35	50·7	50	Hatched
11	...	...	2	35	50·2	50	Sterilised
12	...	...	5	35	50	50	Hatched
13	...	...	3	40	50	50	Sterilised
14	...	...	6	40	50	50	„
15	...	...	5	40	49·7	50	„
16	...	...	3	40	50·4	50	Hatched
17	...	...	2	40	50·3	50	Sterilised
18	...	...	4	40	50·6	50	„
19	...	...	4	40	50·6	50	Hatched
20	...	...	5	40	50·2	50	„
21	...	...	4	45	50·6	50	Sterilised
22	...	...	4	45	50·6	50	„
23	...	...	5	45	50·2	50	„
24	...	...	5	50	50·2	50	Hatched
25	...	...	5	50	50·2	50	„
26	...	...	5	50	50·2	50	Sterilised
27	...	...	5	55	50·3	50	„
28	...	...	5	55	50·3	50	„
29	...	...	5	55	50·3	50	„
30	...	...	5	55	50·3	50	„

TABLE IVB.
Temperature desired, 55° C.

Experiment No.	Age of Eggs when heated, in Days.	Heating, Time in Minutes.	Average Air Temperature of Oven in ° C.	Maximum Temperature reached on Surface of Bean, ° C.	Result.
1	7	15	55	50	Hatched
2	6	20	55	54	"
3	4	20	54.7	54	Sterilised
4	2	20	55.2	54	Hatched
5	3	20	55.9	54	"
6	4	20	54.7	54	"
7	4	25	54.7	55	Sterilised
8	3	25	55.7	55	"
9	3	25	55.7	55	Hatched
10	4	25	55.1	55	Sterilised
11	7	30	55	55	"
12	7	30	55	55	"
13	3	30	55.1	55	"
14	3	30	55.6	55	"
15	3	30	55.6	55	"
16	4	30	55.4	55	Hatched
17	4	30	55.4	55	Sterilised
18	?	35	55.3	55	"
19	3	35	55.5	55	"
20	3	35	55.5	55	Hatched
21	4	35	55.3	55	Sterilised
22	4	35	55.3	55	"
23	3	40	55	55	"
24	3	40	54.9	55	"
25	4	40	54.9	55	"
26	4	40	54.9	55	"
27	4	40	54.9	55	"
28	5	45	55.4	55	"
29	5	45	55.4	55	"
30	5	45	55.4	55	"

TABLE IVc.
Temperature desired, 60° C.

Experiment No.	Age of Eggs when heated, in Days.	Heating, Time in Minutes.	Average Air Temperature of Oven in ° C.	Maximum Temperature reached on Surface of Bean, ° C.	Result.
1	6	15	60	54	Hatched
2	3	20	60	58	"
3	2	20	60·7	58	Sterilised
4	1	20	60·7	58	"
5	2	20	61·2	58	"
6	2	20	60·2	58	"
7	4	25	60	58	"
8	2	25	60·8	58	Hatched
9	1	25	60·8	58	Sterilised
10	2	25	61·4	58	"
11	2	25	60·3	58	Hatched
12	2	25	60·3	58	Sterilised
13	2	30	60·8	58	"
14	1	30	60·8	58	"
15	2	30	61·4	58	"
16	2	30	60·3	58	"
17	2	30	60·3	58	"
18	2	30	60·3	58	Hatched
19	2	35	60·8	59	Sterilised
20	1	35	60·8	59	"
21	2	35	61·4	59	"
22	2	35	60·3	59	"
23	2	35	60·3	59	Hatched
24	2	35	60·3	59	Sterilised
25	2	40	60·4	59	"
26	2	40	60·4	59	"
27	2	40	60·6	59	"
28	2	40	60·6	59	"
29	4	40	60·5	59	"
30	4	40	60·5	59	"
31	2	40	60·3	59	"
32	2	40	60·5	59	"
33	4	40	59·2	59	"
34	4	40	59·2	59	"
35	4	40	60	59	"

TABLE IVd.

Temperature desired, 65° C.

Experiment No.	Age of Eggs when heated, in Days.	Heating, Time in Minutes.	Average Air Temperature of Oven in ° C.	Maximum Temperature reached on Surface of Bean, ° C.	Result.	
1	...	4	10	64.4	54	Sterilised
2	...	2	10	65	54	"
3	...	3	10	64.3	54	"
4	...	3	10	65.4	54	Hatched
5	...	3	10	65.4	54	"
6	...	4	15	65	60	"
7	...	6	15	64	60	Sterilised
8	...	3	15	65.5	60	"
9	...	3	15	65.5	60	"
10	...	4	15	65	60	Hatched
11	...	4	20	64	62	"
12	...	3	20	64	62	Sterilised
13	...	3	20	65.5	62	"
14	...	3	20	65.5	62	Hatched
15	...	4	20	65	62	Sterilised
16	...	5	20	65.6	62	"
17	...	3	25	64	62	"
18	...	3	25	65	62	"
19	...	3	25	65.3	62	"
20	...	3	25	65.3	62	"
21	...	5	25	65	62	"
22	...	5	25	65.7	62	"
23	...	3	30	65.1	63	"
24	...	3	30	65.1	63	"
25	...	5	30	65	63	"
26	...	5	30	65.8	63	"
27	...	5	35	65	63	"
28	...	5	35	65	63	"
29	...	1	35	65.8	63	"
30	...	5	35	65.5	63	"
31	...	3	40	65.3	63	"
32	...	3	40	65.3	63	"
33	...	1	40	66.2	63	"
34	...	3	40	65.1	63	"
35	...	1	40	64.9	63	"
36	...	1	40	65.1	63	"
37	...	1	40	64.9	63	"

TABLE IVe.
Temperature desired, 70° C.

Experiment No.	Age of Eggs when heated, in Days.	Heating, Time in Minutes.	Average Air Temperature of Oven in ° C.	Maximum Temperature reached on Surface of Bean, ° C.	Result.
1	4	10	69.6	60	Hatched
2	4	10	69.6	60	"
3	1	10	69.6	60	Sterilised
4	4	10	71.9	60	Hatched
5	4	15	69.5	66	"
6	4	15	71.7	66	"
7	3	15	69.9	66	Sterilised
8	3	15	69.9	66	Hatched
9	3	15	69.9	66	"
10	4	15	70	66	Sterilised
11	4	15	70	66	Hatched
12	4	20	69.5	68	Sterilised
13	4	20	70.4	68	"
14	3	20	70.2	68	"
15	3	20	70.2	68	Hatched
16	3	20	70.2	68	Sterilised
17	4	20	70	68	"
18	4	20	70	68	"
19	3	25	70.2	70	"
20	3	25	70.2	70	Hatched
21	3	25	70.2	70	"
22	4	25	70	70	Sterilised
23	4	25	70	70	"
24	3	30	70.3	70	"
25	4	30	70.1	70	"
26	4	30	70.1	70	"
27	1	35	70.3	70	"
28	1	35	70.3	70	"
29	1	40	70.3	70	"
30	1	40	70.3	70	"
31	1	40	70.3	70	"
32	1	45	70.5	70	"
33	1	45	70.5	70	"
34	1	45	70.5	70	"

The figures given below do not and cannot, therefore, refer to large quantities, as the air temperature and times required in this latter case would vary with the quantity of beans.

Of the temperatures experimented with (for use in heat treatment of cocoa beans) to destroy the eggs, larvae and pupae of moths, those most likely to give satisfactory results are 60° C. and 65° C., and of these less time would be required for treatment at 65° C. than at 60° C. When the beans are all equally subjected to the heat, the minimum exposure necessary under ideal conditions to effect the complete destruction of all stages of the moth at 60° C. is 40 minutes, and at 65° C., 30 minutes. A minimum exposure of 40–45 minutes at 55° C. would be required, but in the case of every stage of the moth 50° C. appears to be too low to give satisfactory results, except where time is not of importance and where for any reason the use of a higher temperature might be undesirable. The temperature of 70° C. might be considered somewhat too high for treatment of cocoa beans, but if, in this case, time were of importance, and a machine were used to effect the treatment, shorter exposures could be successfully given with this and higher temperatures.

Fumigation.

With a view to finding a suitable fumigant for finished chocolates some tests with various gases, and mixtures of gases, were carried out on the eggs, moths, larvae and pupae of *P. interpunctella* and *E. clutella*, but owing to the obvious disadvantages attendant on the use of most of these gases the experiments were not pursued far enough to give complete results.

Carbon Dioxide alone.

It was considered possible that treatment by various vapours could be rendered more effective if used in combination with carbon dioxide and that the inflammability of certain gases might be reduced by its addition. In order to determine the effect of this gas a separate control experiment was carried out.

Three jars with chocolates were each infested with one pair of *E. clutella* moths five days before experimenting, and a number of eggs were laid. These jars, containing the chocolates, moths and eggs, were placed together in the desiccator and carbon dioxide was drawn in by vacuum suction. They were exposed for 90 minutes, after which it was found that the moths had all survived and the eggs, later, hatched and developed normally.

It is evident from this experiment that the cocoa moth and its eggs are quite unaffected by exposure to carbon dioxide for 1½ hours.

Carbon Dioxide saturated with Carbon Tetrachloride.

Carbon tetrachloride has been used as a fumigant with indifferent success. It has, however, the great merit of being non-inflammable, and it was hoped that the mixture with carbon dioxide would be sufficiently toxic.

Six tests were made on the larvae of *Plodia interpunctella*, the Indian meal moth, with carbon dioxide bubbled through carbon tetrachloride at 21° C. and saturated with this gas. The larvae in each case were placed in a small jar into which the gas was passed, one minute being allowed for the jar to become filled with the vapour. The times of exposure to the gas were 5, 10, 30 and 60 minutes, and two periods of 90 minutes. In the first four tests three larvae were exposed, and in the last two, six larvae. After exposure the larvae were in every case placed in sterilised jars containing some broken chocolates as food should they survive, and the mouth of the jar being covered with a calico lid to permit ventilation, they were incubated at 80° F.

In the 5 minutes' test all three larvae survived, two of them later pupating and emerging as moths. Condensation of the gas took place in the jar, moistening the

larvae in the 10, 30, 60 minutes' and one 90 minutes' test. The larvae in these tests became blackened in parts from the effect of the moisture, but those in the 10 minutes' test survived for three days after treatment, and one in the 30 minutes' for one day.

To prevent condensation taking place in the last test the jar in which the larvae were placed was stood in a basin of water maintained at 4° C. higher than the carbon tetrachloride through which the carbon dioxide was bubbled. In this case none of the larvae was discoloured, and in three days all had recovered, while shortly afterwards one pupated. None, however, succeeded in becoming moths.

It will be seen from these results that the treatment was not sufficiently effective to warrant further experiment, especially since it has the great disadvantage of being liable to lead to condensation of carbon tetrachloride on the chocolate.

Carbon Dioxide saturated with Carbon Bisulphide.

Carbon bisulphide has been used frequently as an insecticide, but owing to its inflammability it is dangerous to handle. It was thought that by saturating it with carbon dioxide this danger might be removed, while it might still retain sufficient toxicity to destroy insect life. Another drawback to its use lies in its objectionable odour, but this, it has been stated, is due to impurities.

Larvae and pupae of *P. interpunctella* were exposed to carbon dioxide saturated with carbon bisulphide; the former were subjected to one test of 20 minutes' exposure, two of 30 minutes', and one of 50 minutes', and the pupae to one test of 30 and one of 48 minutes' exposure. The carbon dioxide was drawn through liquid carbon bisulphide at a temperature of 21° C. by vacuum suction, and condensation in the fumigating chamber was prevented by maintaining the latter at 4° C. higher than the liquid carbon bisulphide.

Of the four larvae subjected to 20 minutes' exposure to the gas, one survived, and three died the day after treatment. In the first test of 30 minutes' exposure, out of six larvae, one survived, but in the second test of 30 minutes all the larvae survived and three shortly afterwards pupated and emerged as moths. Three larvae were exposed to the gas in the 50 minutes' test; of these two died, but one recovered from the treatment and spun a cocoon, though it died without pupating.

All three pupae subjected to a 30 minutes' exposure to the gas survived and emerged as moths, but one only of the three exposed for 48 minutes emerged.

It cannot be said that this treatment was successful. The poor results may be due to the weakening of the carbon bisulphide by mixing it with carbon dioxide, and it is also possible that better results might have been obtained with longer exposures.

Vacuum and Carbon Dioxide.

The vacuum method was introduced to ensure penetration of the gas by causing it to replace quickly the air removed by the vacuum, thus increasing its effectiveness.

A test, using a vacuum before and after exposure to carbon dioxide, was made on one pair of *E. clutella* moths and eggs laid on four chocolates contained in a glass jar with a calico lid. The jar was placed in the desiccating chamber and a 27 inch mercurial vacuum was obtained. After 5 minutes' exposure to the vacuum, carbon dioxide was drawn in until equality with the exterior air pressure was reached. Ninety minutes' exposure to carbon dioxide was allowed, after which a 27 inch vacuum was again attained before admitting the air. Both moths were killed, but the eggs were unaffected, and five months afterwards the chocolates were found to be heavily infested with larvae.

This treatment proved unsuccessful, as the eggs were not sterilised.

Vacuum and Carbon Dioxide saturated with Carbon Bisulphide.

It was considered advisable to ascertain what effect a vacuum would have on the eggs and moths of *Ephestia* when used in combination with carbon dioxide saturated with carbon bisulphide. It was thought that the vacuum would perhaps compensate for the weakness of the carbon bisulphide.

Three jars containing four chocolates were each infested with one pair of *E. elutella* moths, four days previous to the commencement of the experiment, and a number of eggs were laid. These jars, with their calico lids left on, were placed together in the desiccating chamber, which was then evacuated to a 27 inch mercurial vacuum. One moth fell from its resting place on the underside of the calico 4 minutes after evacuation commenced, but three other moths still remained at the tops of the jars. After 10 minutes' vacuum, carbon dioxide saturated with carbon bisulphide was blown into the chamber and the three moths fell from their positions within $1\frac{1}{2}$ minutes after this. Four and a half minutes were taken to fill the chamber with gas, after which an exposure of 90 minutes was allowed. The gas was then withdrawn by vacuum, taking $2\frac{1}{2}$ minutes, after which air was let in, but as slight condensation had taken place on some of the chocolates a vacuum was again made for a few minutes to dry them. When the air was let in and the jars removed from the chamber all the moths were found to be dead, but since it was not possible to tell whether the eggs were destroyed, the jars were incubated at 80° F. to give them every opportunity of developing should they be still alive.

About five months afterwards all three jars were opened and the chocolates examined. No sign of any larvae could be found, so it must be concluded that the eggs were sterilised by the treatment.

This treatment was successful, but owing to the liability of the carbon bisulphide to condense on the chocolates, it is clear that it would not be desirable to use it for the sterilisation of chocolates.

Vacuum and Ether plus Carbon Dioxide.

Two separate tests with ether and carbon dioxide, using a vacuum before and after admitting the gas, were carried out.

One pair of *E. elutella* moths and eggs on chocolates contained in a glass jar were placed in the desiccating chamber and a 27 inch mercurial vacuum was obtained. After 5 minutes' vacuum, ether and carbon dioxide were drawn into the desiccator, but in filling the chamber condensation of the ether took place on the chocolates at 12 in. An exposure of 90 minutes was allowed before again evacuating the chamber to 27 in. The vacuum was maintained for 5 minutes, after which air was admitted.

The moths in this test were both killed and none of the eggs developed.

In the second test four full-grown larvae were placed in the jar in addition to the pair of moths and the eggs on the chocolates. To prevent the occurrence of condensation the procedure was slightly altered. The jar was placed in a desiccator and a 27 inch vacuum obtained. After 5 minutes' vacuum, carbon dioxide alone was admitted until the mercury fell to 14 in., then the ether and carbon dioxide were drawn in until 2 in. was reached, after which carbon dioxide alone was again admitted, until the pressure of gas in the chamber was equal to that of the air outside. An exposure of 90 minutes to the gas was allowed, before again evacuating the chamber to 27 in. and admitting air.

In this test no condensation of ether took place. One moth and three of the full-grown larvae survived, and after five months the chocolates were found to be heavily infested with larvae which had developed from the eggs.

From the result of the second test it will be seen that the destruction of life in the first was due to the condensation of the ether actually on the moths and their eggs, and that when condensation was prevented the insects were not seriously affected by the treatment.

Vacuum and Nitrous Oxide.

A jar containing a pair of *E. elutella* moths and four chocolates on which eggs were laid was placed in the desiccator and a 27 inch vacuum was obtained. Five minutes' exposure to the vacuum was allowed, after which nitrous oxide was drawn into the chamber until the pressure of the gas inside was equal to the air pressure outside. An exposure of 90 minutes was given, after which a 27 inch vacuum was again produced and maintained for 5 minutes before admitting air. The moths remained perfectly still throughout the experiment, but recovered immediately on the admission of air; the eggs also survived.

Another test, exactly similar to the former, was made, except that a 26 inch mercurial vacuum was obtained before and after the admission of the nitrous oxide instead of a 27 inch vacuum, and that the period of exposure to the gas was in this case 3 hours. Both the moths survived the treatment and the eggs were unaffected, the chocolates being heavily infested with larvae developed from these, when examined five months later.

This treatment was entirely unsuccessful, the insects being quite unaffected even after such a long exposure to the nitrous oxide as 3 hours.

Vacuum and Ethyl Acetate.

The article by E. A. Back & R. T. Cotton on "Ethyl Acetate in Combination with Carbon Tetrachloride,"³ having been brought to our notice at the laboratory, it was decided to make some experiments on *Ephestia* eggs and larvae, using ethyl acetate alone. It is stated that the new mixture is practically as effective as carbon bisulphide, while at the same time it is made non-inflammable by the greater proportion of the carbon tetrachloride to the ethyl acetate, and it has no disagreeable odour. The reason for experimenting with the ethyl acetate alone was that it is the killing agent, the carbon tetrachloride, which has little toxicity, being only used to make a non-inflammable mixture.

In the first experiment a vacuum was used before and after the exposure to the ethyl acetate in order to compare the results with the previous experiments.

In the first test six larvae were placed on an open petri dish in the desiccator and a vacuum of 25-27 inches was maintained for 5 minutes, after which ethyl acetate was drawn in. An exposure to the gas of 3 hours was allowed from the time when the chamber was full, and only very slight condensation occurred. At the end of this time the desiccator was again evacuated for 5 minutes before admitting air.

The larvae were affected almost immediately on the entrance of the ethyl acetate, and three, which were at the top of the jar, fell from their positions in a few minutes. After treatment they were placed in a sterilised jar with cocoa beans, and being covered with a calico lid, they were then incubated at 80° F. and had every opportunity to recover. None, however, survived the treatment.

Three other tests were made exactly similar to the first except that the exposures to the ethyl acetate were for 2 hours, 1½ hours, and ½ hour. Six larvae were exposed in each case and incubated after treatment. No condensation occurred in these tests, and none of the larvae recovered from the effects of the fumigation. Some eggs laid by *E. elutella* moths on cocoa beans were also treated in the second test at the same time as the larvae, and given with them 2 hours' exposure to the ethyl acetate. None of these eggs developed after the treatment.

This treatment proved successful with both the eggs and the larvae, the former being destroyed after 2 hours' exposure to the ethyl acetate, and the latter after the very short exposure of $\frac{1}{2}$ hour.

Effect of Vacuum Treatment on Chocolates.

In order to find out what effect the vacuum together with the ethyl acetate would have on chocolates, three were placed in the desiccator and treated in the same way as the eggs and larvae had been, for 2 hours, in the above tests.

A very few minutes after the vacuum commenced two of the chocolates which had cream centres burst, but closed up again on the admission of the gas. The chocolates used in previous vacuum and gas experiments all had nut centres and this accounts for the fact that they failed to burst. Ethyl acetate also condensed on the surface of the chocolates treated with a vacuum, causing them to become very soft and moist.

Ethyl Acetate without Vacuum.

It is obvious that it would be dangerous to employ a process of sterilisation involving the danger of bursting the chocolates and consequently vacuum treatment is impracticable. The previous experiments with ethyl acetate had, however, given good results when compared with those vacuum and gas experiments already made. It was, therefore, decided to try the effect of fumigation with ethyl acetate alone, without using a vacuum before and after.

Six larvae were placed in one open petri dish and some eggs, laid on three cocoa beans, in another. These were both placed in the desiccator at the same time and subjected to fumigation with ethyl acetate for 2 hours. After treatment the larvae and eggs on cocoa beans were placed in two separate jars and incubated. The larvae failed to recover and none of the eggs survived. In the same way larvae and eggs were subjected to fumigation with ethyl acetate for 1 hour and incubated after treatment. In this case, although all the larvae were killed, the eggs hatched, and when the beans on which they had been laid were examined two months later, they were found to be infested with young larvae.

The results of this treatment were successful, the larvae being destroyed after exposure to the gas for 1 hour, and it is evident that the eggs are sterilised at some point between 1 and 2 hours' exposure, since they succeeded in hatching after fumigation for 1 hour, but failed to develop after 2 hours' treatment.

Effect of Ethyl Acetate Fumigation on Chocolates (without Vacuum).

Three chocolates were fumigated with ethyl acetate for 2 hours and three for 1 hour, both sets being placed in the desiccator on open petri dishes. On examination after treatment the chocolates in both tests were found to have a very slight bloom in small patches on their surfaces, though during fumigation no moisture was seen on them.

Fumigation of Chocolates in Boxes with Ethyl Acetate and Carbon Tetrachloride.

The above experiments with ethyl acetate having proved so promising in comparison with the other fumigation experiments carried out, it was decided to ascertain whether a box of chocolates infested with all stages of the cocoa moth could be satisfactorily treated with ethyl acetate in combination with carbon tetrachloride, using the proportions recommended by Back & Cotton.

Accordingly, a deep box containing two layers of chocolates with the usual paper packing was infested with all stages of *E. elutella*. In the bottom layer 30 loose, recently laid eggs were placed on and about the chocolates, 10 full-grown larvae, 4 pupae and 4 moths were also put in, and the same number of each were put into the top layer, after which the lid was closed.

In order to carry out the fumigation the box of chocolates was placed in a desiccator and air, blown through liquid ethyl acetate and carbon tetrachloride in the proportion of 40 : 60 parts, respectively, was passed into it. Thirty minutes were allowed to fill the desiccator, in addition to the 24 hours' exposure.

At the end of the treatment the desiccator was again opened, and the box of chocolates removed and examined throughout. All the moths and larvae were found to be dead, and the pupae, after incubation for 18 days, failed to emerge and appeared shrunken and lifeless. The box containing the chocolates, after having been kept in the laboratory for 18 days (incubation being impossible), was again opened and carefully searched. All the eggs were collected and counted. None of them had succeeded in hatching and all were yellow and collapsed. Thus, by an exposure to the gas of 24 hours total destruction of all stages of the moth was effected, though it will be noted that, owing to the difficulty of obtaining infested chocolates, no larvae were actually inside them. Consequently, it is impossible to say whether the gas would be able to penetrate the chocolates inside a box and destroy larvae within them.

A second box of chocolates of exactly the same size and containing approximately the same number of chocolates as the first was infested with eggs, larvae, pupae and moths of *E. elutella* as before, and fumigated with ethyl acetate and carbon tetrachloride for 8 hours.

In this box, after treatment, it was found that all the moths were dead, but of the 20 larvae put in 6 had survived, though 2 of them died some days later. The pupae were incubated, and although sufficient time was allowed, no moths emerged, and on examination they were found to be dead. The box containing the chocolates and eggs was kept in the laboratory for a fortnight, after which as many eggs as could be found were collected and counted. In doing this, it was proved that the imprisoned moths had laid additional eggs in the interval which elapsed between the infesting of the box and the fumigation. All the eggs found appeared to have been destroyed, but it seems probable that some may have survived, though at the time of writing it is impossible to say whether this is so. But the fact that several full-grown larvae survived the treatment is, in itself, sufficient to show that fumigation for 8 hours is not enough to ensure complete destruction of insect life.

From these two experiments it will be seen that the minimum exposure to the fumes of ethyl acetate and carbon tetrachloride necessary to exterminate moth in boxes of chocolates lies between 8 and 24 hours.

The slight odour of the fumigant which was noticeable in the chocolates immediately after the treatment entirely disappeared after a short time, although both boxes were kept tightly closed.

Conclusion.

This set of experiments with ethyl acetate alone, and in combination with carbon tetrachloride, proved the most successful of all the fumigation tests that were carried out, and it was found that the gas was capable of penetrating and destroying all stages of the moth inside comparatively tightly packed boxes of chocolates, when

sufficient time was allowed. It should, however, be remembered, that in fumigating with any gas, unless extreme care were taken, there would always be a tendency towards condensation taking place on the surface of the chocolate.

Moth Traps in Packing and Store Rooms.

Various expedients have been tried in factories for trapping moths with a view to keeping their numbers in check in store and packing rooms, where it is impossible to exterminate them entirely.

W. G. Johnson, in his paper on "The Mediterranean Flour Moth (*E. kühniella*, Zell.) in Europe and America" 1895,¹⁷ gives several methods of trapping found to be very effective in flour mills. A miller accidentally discovered the attraction which flour paste has for the moth and made a series of experiments with it as a trap. The paste was made with flour, water and vinegar, and boiled by steam. This was poured into shallow pans and placed about the factory at night. The moths were attracted to it, fell in, and were unable to escape. But it was necessary for it to be in a certain stage of fermentation. The numbers of moths were greatly reduced; but the cost of the paste was considerable, as it had to be renewed every few days to be of service. Vinegar and water, 1 : 3, was then found to have the same attraction for the moths, and as it lasted until it evaporated and did not require to be renewed as often as the flour paste, he abandoned the paste in its favour. It, however, corroded the pans very badly. He next tried vinegar and molasses, 1 : 3, stirred well together, and found it to be even better than the two former mixtures, as it lasted longer and required less attention. Fly-papers were also found effective when placed about the mill at night, 50-100 moths being caught on a single sheet in one night, but they were expensive for use in mills. Coal tar smeared on large pieces of heavy paper was found useful, but the tar dried rapidly and had to be renewed every 24 hours. A mixture of coal tar and vaseline, in equal proportions, though no better, was found to dry less rapidly than the above and was therefore preferable. Johnson further mentions that in an outbreak of moth in Germany in 1858 a miller in the hay season placed hay ropes about the mill. The moths collected in these in large numbers, and he was able to gather them up and burn them each week.

Zipperer, in "The Manufacture of Chocolate,"³⁷ says that it is best to destroy the moths in the warehouses in the months of June, July and August, and that, according to Hauswaldt, Stollwerck¹⁶ and G. Reinhardt,³¹ this is best effected by placing shallow pans of water about the store-rooms at night and putting near each a petroleum lamp so that the light is reflected on the water. He says that the moths are attracted by the light and are either burnt or fall in and drown. The water, however, must be changed every day, otherwise the film of dust collecting on the surface permits the moths to escape.

In the "Review of Applied Entomology,"²⁰ *E. elutella* is mentioned as injuring earthenware cake, and trapping is recommended as a check. Ordinary earthen pots were used containing 10 per cent. solution of molasses. In the same publication (p. 726) *E. elutella* is mentioned as attacking ground-nuts, and molasses and water, 1 : 9, is again suggested as a trap.

A. W. Knapp states that it is the practice in some stores to place pieces of cardboard smeared with birdlime or sticky material on the floors to prevent the caterpillars passing from one stack of beans to another. This is done in September, when the full-fed larvae are searching for a place to spin their cocoons. He says that boiled linseed-oil preparations are best, and that "Bandite" and preparations such as are used for grease-banding trees are very good. The "Gordian" states that the most effective method of destroying *E. elutella* is by placing sticky paper near an electric light. Knapp, however, says that the moths he observed were exceptional in not being attracted by bright lights. He tried glass globes illuminated internally by electric

light and smeared externally with adhesive, but caught no moths. He goes on to say that there is no doubt of the attraction of pans of liquid for moths and mentions the extraordinary attraction which tea, prepared as for drinking with milk and sugar, has for them. He says it is even more effective than cocoa.

In the "Care of Sweets" (MacRobertson's²⁶) it is stated that moths can be caught by smearing treacle and honey on paper, to which they stick.

By means of a letter of introduction, kindly given us by H.M. Customs and Excise, we were enabled to visit the cocoa warehouse at the London Docks in order to see the condition of the beans in the store. Our first visit took place in May, when there were very few moths about, but the foreman showed us over the warehouse, and we were able to examine some beans and collect a few specimens.

The building is very large, several stories high, brick built, with wooden floors and rafters across the ceilings of each section. The brick walls are whitewashed inside, but all the woodwork is left rough. There are two or more lift shafts running through each floor, protected with wooden laths, and also a staircase, many large windows, and in every section a double door opening to the outside for hoisting up sacks from below. The floors on the same level are separated from one another by fireproof doors. In spite of the large windows and open doors the sections are very dark and this is accentuated where the bags are stacked in high piles. There is also very little draught and the air is usually quite still.

We saw some bags of beans which had remained in the warehouse for two years. These were heavily infested with *Ephestia elutella* larvae and also *Plinus tectus*. Fresh material, newly arrived, is often placed immediately in contact with old infested stock. The foremen, however, do all possible without technical assistance to keep down the pest, by sweeping the bags over regularly and thus removing some of the larvae as they appear. We were informed that the moths are very numerous in the summer months and that the numbers of larvae increase greatly in September and October. Arrangements were made for further visits when the moths should begin to appear.

On 28th June, having heard that the moths were emerging in great numbers, we again visited the warehouse, thinking it an opportunity to make some experiments with traps. But at the same time we realised that these could only be useful in packing and store rooms of factories where a few stray moths cause the trouble, and that where they are in such myriads, as in this case, traps would not be of material assistance. We found the moths in this warehouse throughout our experiments to be *Ephestia elutella*.

There are two things which attract moths in general, light and smell. We determined to try the latter first, as this seemed, according to the references in other papers, more likely to be successful. It was arranged, therefore, to place about a section of the warehouse, where they would not be disturbed and where the moths were numerous, shallow pans of various liquids, which after two to three days could be examined and the moths caught in them counted.

Experiment I.

In our first experiment the mixtures used were as follows :—

- (1) Water (as control).
- (2) Vinegar and fermenting fruit-syrup (orange), 1 : 3.
- (3) Beer and cocoa, 3 : 1 (stout was used).
- (4) Flour and vinegar, 1 : 3.
- (5) Vinegar and water, 3 : 1.

These were arranged in five series according to position with regard to : (1) light ; (2) height from the floor. In every series there were five pans, each measuring $8\frac{1}{2}$ in. in diameter by $1\frac{1}{2}$ in. in depth, and there was one pan of each mixture in every series. Thus, there were 25 pans in all. The pans in a single series were always placed on the same level as each other and about a foot apart, but in various positions. After two days we again visited the warehouse to collect the pans and count the moths caught in each. The results are given in Table V.

TABLE V.
SET 28.vi.1927. CHECKED 30.vi.1927.

Series.	Position.	Mixtures.				
		(Control) Water.	Vinegar and Syrup.	Beer and Cocoa.	Flour and Vinegar.	Vinegar and Water.
1	Window-sill	71	237	204	226	161
2	Near windows, lift shaft on floor ; light	8	120	75	70	88
3	On sacks ; three-quarter light ...	29	148	167	162	146
4	On sacks ; darkish	11	150	135	129	79
5	On floor ; dark	7	57	53	58	25
Total number of moths caught by each mixture		126	712	634	645	499

In this experiment vinegar and syrup appeared to be the most successful mixture. In three series out of five, it trapped the highest number of moths, and comparing the total number of moths caught by each liquid it trapped 67 more than flour and vinegar, which comes second.

The number of moths caught by the control, i.e., water, was appreciably lower than that trapped by the remaining four liquids, which seems to indicate that the moths are attracted by smell.

As regards position, Series I, placed on the window-sill, was decidedly the most successful, and the difference between the total number of moths caught by each series, with the exception of Series 2, goes to prove that traps are more or less successful according to the light and height at which they are placed. Those traps which are in light places and raised from the floor seem to attract more moths than those which are in dark places and on the floor.

The low results of Series 2 are somewhat remarkable and may be due to the fact that the traps were placed on the floor, in a passage way about 3 ft. wide, between two lift shafts and about 5 yards from a window. It is possible that the draught of air up these shafts caused the moths, when they flew from the woodwork on which they rested, to rise, and thus tended to prevent them from reaching the traps on the floor.

Experiment II.

This experiment was carried out over a week-end in all five days, a period rather too long, as some of the mixtures evaporated and others became mouldy. This happened respectively in the case of flour and water, and in that of cocoa and water. The mixtures used here were :—

1. Water (as control).
2. Flour and water, 1 : 3.
3. Cocoa and water, 1 : 3.

There were five series of three pans each. The position of each series was identical with that of Experiment I. The results are shown in Table VI.

TABLE VI.

SET 30.vi.1927. CHECKED 5.vii.1927.

Series.	Position.	Mixtures.		
		(Control) Water.	Flour and Water.	Cocoa and Water.
1	Window-sill	144	78	172
2	Near windows, lift shafts, on floor ; light ...	85	94	58
3	On sacks ; three-quarter light	122	102	135
4	On sacks ; darkish	178	56	70
5	On floor ; dark	79	58	78
Total number of moths caught by each mixture ...		608	388	513

Here the water (control) and the cocoa and water appeared to be about equally effective, but the water obtained the highest total number of moths, owing to its not having evaporated to a noticeable extent. The flour and water trapped fewer moths than either of the other liquids, but this may be due to the fact that the water evaporated quickly, and left the flour set hard and dry, whereas the cocoa and water remained moist after the surplus water had evaporated.

With regard to the efficiency of the liquids in relation to the positions in which they were placed, the same conclusions may be drawn as in Experiment I. Series 1, placed on the window-sill, and Series 3, placed on sacks in a fairly light position, caught more moths than Series 4 and 5, which were, respectively, on sacks in a darkish place and on the floor in the dark.

Series 2 again shows a low count in comparison with 1 and 3, and this is probably due, as in Experiment I, to the draught from the lift shafts between which the pans were placed. This experiment shows that the mixtures of flour and water, and cocoa and water, are really no more effective in trapping the moths than plain water. It, however, proves that it is not the flour or the cocoa which is the attracting substance, but the water or whatever liquid is used. By comparing the total number of moths caught in each of the four mixtures of Experiment I and the total caught by each of the two mixtures of Experiment II with the controls, i.e., water, of these two experiments, it may be seen that it is the vinegar or fermenting liquid which directly attracts the moths.

In consequence of this result we abandoned the flour and cocoa in our further experiments.

Experiment III.

This experiment lasted for three days. The mixtures used were as follows :—

1. Water (as control).
2. Vinegar and water, 3 : 1.
3. Vinegar and sugar with a little water.

These were arranged in seven series according to: (1) the light ; and (2) the height from the floor at which they were placed. There were three pans to each series, in all 21 pans.

TABLE VII.
SET 5.vii.1927. CHECKED 8.vii.1927.

Series.	Position.	Mixtures.		
		(Control) Water.	Vinegar and Water.	Vinegar and Sugar.
1	Window-sill	230	400	329
2	Below window-sill ; three-quarter light ...	173	192	217
3	On sacks ; three-quarter light	107	145	188
4	On sacks ; half shadow (another section of warehouse)	153	185	231
5	On floor ; half shadow (other side of sacks) ...	109	154	164
6	On sacks ; three-quarter shadow	9	165	126
7	On floor ; deep shadow	84	168	169
Total number of moths caught by each mixture ...		865	1,403	1,424

The most successful mixture in this experiment was the vinegar and sugar. In five out of seven series it trapped the greatest number of moths, and its total is higher than either of the other two liquids. The vinegar and water, however, was very nearly as good as the vinegar and sugar, and in Series I it alone caught 400 moths.

Here again it will be seen that the most successful series are those which were placed in the best light. That the results of Series 4 are higher than those of 3 may be accounted for in that this series was placed in another section of the warehouse from the others. Series 7 was placed in a position where the number of moths was very great indeed, and on the other side of the partition from Series 6. This may account for the number of moths trapped by it being greater than that caught by Series 6, in spite of its being placed in deep shadow and on the floor.

Experiment IV.

This experiment also lasted three days. The mixtures were as follows :—

1. Water (as control).
2. Vinegar and water, 3 : 1.
3. Vinegar and syrup, 1 : 3.
4. Syrup and water, 3 : 1.

(Syrup used was cherry and orange mixed, fermenting.)

There were five series of four pans each, making altogether 20 pans.

TABLE VIII.
SET 8.vii.1927. CHECKED 11.vii.1927.

Series.	Position.	Mixtures.			
		(Control) Water.	Vinegar and Water.	Vinegar and Syrup.	Syrup and Water.
1	Window-sill	133	365	243	202
2	Below window-sill, beyond shadow cast by it ; on floor	178	213	365	212
3	On sacks ; three-quarter light	53	167	158	177
4	On sacks ; three-quarter shadow	58	98	162	176
5	On floor ; deep shadow	54	97	165	105
Total number of moths caught by each mixture		476	940	1,093	872

The mixture of vinegar and syrup was, in this experiment, the most successful, trapping by far the highest total number of moths. The vinegar and water, and then the syrup and water, were, respectively, the next best.

It will be noticed that the results of Series 2 are higher in this experiment than those of Series 2 in Experiment III. This is due to the fact that the pans were placed just beyond the shadow cast by the window-sill and were, therefore, in better light than those in Experiment III. Again, this experiment indicates the greatest success of traps placed in light positions, and, as a rule, those which are raised from the floor.

Illuminated Water Traps.

It was thought advisable when the above liquid trap experiments were being carried out to test the efficacy of light traps, about which opinions varied. Accordingly, two moulded glass bowls, filled with clear water, were placed resting on the tops of two electric torches, and put in two different positions, among sacks, where many moths were seen to be flying. The light shone up through the water, making a bright, reflecting surface. These torches were left burning overnight for 16 hours, but on examining the bowls the next day very few moths were found to have been caught, and we concluded that bright light did not attract this species of moth. This result did not warrant a repetition of the experiment, when comparing the numbers caught with those trapped by the mixtures, and we therefore abandoned light traps as being ineffective.

Fly Papers.

Two sheets of heavy paper smeared with an adhesive mixture made with linseed-oil, cocoa and vanilla, were hung among the sacks in the warehouse, where numbers of moths were seen flying. These were exposed for two days, but with absolutely no result. Not a single moth was caught on either, and as a consequence the experiment was not considered worth repeating.

Conclusion.

1. On the whole, the most successful mixture of those experimented with proved to be vinegar and fermenting fruit syrup. The concentration of vinegar which it is most desirable to use, bearing in mind both efficiency and cost, will, of necessity, have to be ascertained in the factory. In the experiments referred to in this report the proportion of vinegar to syrup was, in general, 1 : 3, but it is possible that this proportion might be considerably reduced.

2. It was proved that it is the smell which attracts the moths, in that they are caught in far greater numbers by the vinegar and fermenting fruit syrup mixtures, than by the plain water of flour and water mixtures.

3. Those traps which were placed in a good diffused light (daylight near windows) were more successful than those placed in the shadow or dark places.

4. Traps raised in some way were generally more successful than those which were placed on the floor. When making our experiments at the warehouse we noticed that a number of moths are regularly caught in the water of the fire buckets.

5. Illuminated water traps were not successful.

IV. RECOMMENDATIONS.

The sources of infestation of cocoa beans by moths are the plantation, the ship and the docks. On arrival at the factory the beans may be infested and cannot, in any case, be regarded as entirely free.

From the beans in the store, infection may, and does, spread to the rest of the factory. Stray moths may be found in warm places throughout the year, becoming, of course, greater in number during the summer. Such stray moths are always liable to lay eggs on, or in the vicinity of, finished goods, so that development may occur after the goods are packed.

In addition, therefore, to the damage and waste caused by moths and their larvae as regards raw beans, there is always the danger that a customer may find all the evidences of attack in a box of chocolates which on packing has appeared perfectly sound.

The problem, therefore, reduces itself to prevention of :—

- (a) Damage to beans in the raw state.
- (b) Infestation spreading to the factory.
- (c) Infestation of finished chocolate. It has been found that insect life does not survive the processes of manufacture.

The first of these steps must be taken at the docks, either by heat treatment or by some form of fumigation, but this whole question is now under consideration by the Empire Marketing Board, and it is not possible at the moment to do more than draw attention to the problem.

The scope of the present report relates chiefly, therefore, to steps to be taken in cocoa and chocolate factories.

The first and most important precaution is to ensure that all insect life in the beans shall be destroyed on arrival at the factory. This is by no means impossible, and in fact, has in some factories, at any rate, been found to be relatively simple.

As the report shows, it is only necessary to subject the beans to the moderately high temperature $60^{\circ}\text{C}.$ – $65^{\circ}\text{C}.$ ($140^{\circ}\text{F}.$ – $149^{\circ}\text{F}.$) for a time which will depend on the quantity of material to be dealt with. The beans, however, should be in the hot chamber long enough to enable all of them actually to attain to this temperature for an appreciable time. The total time necessary for treatment in the hot chamber at this air temperature in order to sterilise any given quantity of beans can, therefore, only be ascertained by experience.

The heat treatment at $60^{\circ}\text{C}.$ – $65^{\circ}\text{C}.$ destroys all moths, larvae, pupae and eggs. Knapp has found that, provided the temperature of $160^{\circ}\text{F}.$ ($71^{\circ}\text{C}.$) is not exceeded, the cocoa is not detrimentally affected.

There is, however, in nearly all cases, an already existing infestation of the factory store, so that not only is there a liability of the finished goods to attack by moths, but the sterilised beans may actually be re-infected. Beans which have been sterilised must, therefore, be placed in stores already freed from infestation.

Further, some means must be taken to destroy, as far as possible, the stray moths in the factory, not only by means of traps, but also by encouraging employees to kill such moths in their respective departments.

With regard to the disinfection of factory premises, the most efficient and practical method available at present is fumigation with hydrocyanic acid, which should, however, be carried out by men specially trained for this work.

It is probable that hydrocyanic acid fumigation of cocoa beans and similar raw materials which are afterwards subjected to a cooking process could be considered unobjectionable.

It is only in the case of finished goods or those which are not afterwards subjected to a cooking process that its use cannot be recommended at present, as various materials appear to absorb and retain the gas to widely different extents.

In the meantime, the following steps are suggested in order to keep the numbers of stray moths down to a minimum, apart from the treatment of beans on arrival at the factory :—

(1) Cleanliness in the factory, frequent whitewashing, distempering, etc. ; removal of waste matter which may form breeding grounds.

(2) The use of traps to catch any stray moths. A mixture of vinegar with fermenting syrup containing a fruit flavour has been found very effective. Long troughs containing a large area of the liquid, but little depth of it, should be placed in convenient places near windows and the moths caught in them destroyed.

(3) The isolation of all finished goods, packed boxes, etc., by means of screens of fine-mesh material.

It would be advantageous if it were possible to recommend some form of harmless fumigation of packed boxes of chocolates so that it would be certain that on leaving the factory they contained no eggs. Although such treatments have been recommended in America there are such serious limitations in the case of covered centres that it is not at the moment possible to make a recommendation which is absolutely safe. It has been found, for instance, that the use of a vacuum combined with the introduction of some such harmless substance as ethyl acetate may destroy the eggs and larvae, but fondants are liable to burst on evacuation and organic fumigants such as those mentioned are very liable to be absorbed by the packing material, and even the chocolate, thus imparting, for a time at least, a noticeable odour and perhaps taste. In addition, there is a possibility of condensation of such volatile substances on the chocolates themselves, thus possibly giving rise to surface defects. It has been found, however, to be a suitable method of treating nuts, as the flavour at first imparted is soon lost on exposing the nuts to the air.

The recommendations thus consist of the treatment of the raw beans, together with prevention of infestation of the finished goods, for it was found that no insect life can survive any part of the process of manufacture of chocolate. Eggs, larvae, etc., are killed, not only by roasting, but also by being covered with melted chocolate, thus causing suffocation even where the temperature alone would not be lethal.

Cocoa would, of course, be liable to infestation when in the powder form and should, therefore, be protected by fine-mesh material in the same way as finished chocolates.

V. SUMMARY.

1. The chief pests of cocoa and chocolate are the Pyralid moths, *Ephestia clutella* (cocoa moth), *E. kühniella* (Mediterranean flour moth), *E. cautella* (fig moth), and *Plodia interpunctella* (Indian meal moth).

2. Beans are infested before arrival at the factory, this infestation commencing on the plantation and increasing during the various stages of transit to the factory. The docks, in particular, may be the most important source of infestation owing to the fact that there fresh consignments may be brought into direct contact with much older consignments already heavily infested.

3. The steps recommended for factory use are :—

(a) General cleanliness in all parts of the factory, avoidance of dead spaces which offer opportunities for breeding and pupation, removal of all waste material, constant sweeping, frequent whitewashing and distempering, etc.

(b) Heat treatment of beans on arrival at the factory and subsequent storage where they will not be liable to re-infestation. The heat treatment to consist of subjection to a temperature of 60° C.–65° C. for a time dependent on quantity of beans.

- (c) The use of traps in the factory in order to keep down the numbers of stray moths. Such traps may consist of vinegar and syrup.
- (d) The protection of all finished goods by means of fine-mesh materials so far as possible.
- 4. No insect life survives either roasting or any stage of manufacture in which the chocolate is in a molten condition.
- 5. Although parasites exist which prey on the larvae of these moths, it is not considered that extermination by means of them would be practicable.
- 6. Fumigation of warehouses, especially at the docks, is under consideration by the Empire Marketing Board, and any recommendation they may make will probably be applicable to factories. At the present stage, however, it is premature to make suggestions.

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COLLECTIONS RECEIVED.

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Prof. C. R. KELLOGG :—24 Coleoptera, 8 Parasitic Hymenoptera, and 2 Planipennia ; from China.

Mr. W. R. S. LADELL :—12 Culicidae, 24 Tabanidae, 184 other Diptera, 20 Dipterous cocoons, 6 Hymenoptera, and 5 Ephemerae ; from Siam.

Dr. S. LEEFMANS :—12 Diptera, 23 Coleoptera, 124 Parasitic Hymenoptera, 4 Formicidae, 55 Lepidoptera, 4 Lepidopterous larvae, and 80 Rhynchota ; from Java.

Messrs. LEVER BROTHERS :—50 Coleoptera and 15 early stages ; from Port Sunlight, Cheshire.

Mr. W. A. McDougall :—6 Parasitic Hymenoptera ; from Queensland, Australia.

Prof. F. J. MEGGITT :—2 Tipulid larvae ; from Burma.

Dr. B. de MEILLON :—11 Rhynchota and 6 Trombididae ; from South Africa.

Mr. J. E. M. MELLOR :—1,383 Diptera ; from Egypt.

Dr. D. MILLER, Chief Entomologist, Cawthron Institute :—1 Scolytid ; from New Zealand.

Mr. H. M. MORRIS, Government Entomologist :—3 Cecidomyiidae and 2 Coleoptera ; from Cyprus.

Dr. A. A. OGLOBLIN :—152 Orthoptera ; from the Argentine Republic.

Mr. R. W. PAINE :—6 Tachinidae, 188 Parasitic Hymenoptera, and 100 Lepidoptera ; from Java.

Prof. G. PAOLI :—16 Coleoptera, 20 Parasitic Hymenoptera, and 2 Lepidoptera ; from the Italian Somaliland.

Mr. A. W. J. POMEROY, Government Entomologist :—1,918 *Glossina* ; from the Gold Coast.

Prof. E. B. POULTON, F.R.S. :—12 Diptera, 12 Coleoptera, 11 Parasitic Hymenoptera, 31 other Hymenoptera, 2 Rhynchota, and 18 Odonata ; from Uganda, Egypt, and Cyprus.

Dr. H. PRIESNER :—300 Parasitic Hymenoptera ; from Egypt.

Mr. Y. R. RAO, Government Entomologist :—108 Coleoptera, 3 Chalcididae, 65 other Hymenoptera, and 200 Rhynchota ; from South India.

Mr. H. W. SIMMONDS :—14 Parasitic Hymenoptera, 1 species of Aleurodidae, and 10 Mites ; from Trinidad.

Mr. E. R. SPEYER :—4 Dipterous pupae ; from Cheshunt, Hertfordshire.

Mr. C. B. SYMES, Medical Entomologist :—1,218 Siphonaptera, 20 Culicidae, and 50 other Diptera ; from Kenya Colony.

Mr. H. P. THOMASSET :—83 Diptera, 26 Coleoptera, 6 Hymenoptera, 162 Lepidoptera, 45 Rhynchota, and 3 Ephemerae ; from Natal.

Dr. R. J. TILLYARD, F.R.S. :—1 species of Aphidae ; from Canberra, Australia.

Mr. F. W. URICH :—326 Culicidae ; from Venezuela.

Mr. R. VEITCH, Chief Entomologist :—3 Diptera and 23 Rhynchota ; from Queensland, Australia.

Mr. F. A. T. H. VERBEEK :—2 Curculionidae ; from Java.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—321 Culicidae ; from the Sudan.

Dr. WILKEN :—15 Shells ; from Tanganyika Territory.

A NEW VARIETY OF *ANOPHELES FUNESTUS*, GILES, FROM SOUTHERN RHODESIA.

By H. S. LEESON,

Department of Entomology, London School of Hygiene and Tropical Medicine.

While investigating the ANOPHELINI of Southern Rhodesia in connection with the research on blackwater fever conducted by the London School of Hygiene and Tropical Medicine, an undescribed variety of *Anopheles funestus*, Giles, was taken in the dry season. Nine males and eight females were collected from May to August 1927, near Shamva, and one male and one female in July 1928, in the Fungwi Native Reserve. All were caught out-of-doors except two females, one of which was taken in a shed constructed of grass and the other in a native hut. The remainder were taken in close association with the earth; in surface drains, caves and crevices in rocks. No specimens were taken in or near European habitations, but all in undeveloped country. No adults were bred out, so that the following description is based on individuals captured "wild." The larva is unknown.

Anopheles funestus var. *fuscivenosus*, nov.

♀. *Head* clothed with black and white upright forked scales; white ones situated towards vertex; long white scales projecting forward from front. *Proboscis* dark brown with paler apex. *Palpi* clothed with dark brown scales; base black: a pale band, very narrow and obscure, situated at apex of first joint; a second pale band, very little wider, situated at apex of second joint; third and terminal pale band very broad, equal to half of fourth joint. *Antennae* all brown; base slightly paler. *Thorax*: general appearance dark brown. Prothoracic lobes with black bristles. Scutum with integument dark brown, covered in certain lights with a greyish bloom; clothed with short hairs, but with long white narrow curved scales towards the front margin. Spiracular hairs apparently absent. One propleural hair. *Scutellum* with black bristles. *Legs* dark brown, unicolorous, except that the articulations of the joints are indistinctly paler. *Wings* (fig. 1): general appearance dark. Costa with

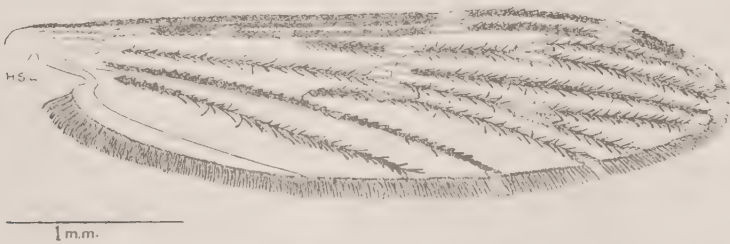


Fig. 1. Wing of *Anopheles funestus* var. *fuscivenosus*, nov.

three pale spots, remainder all dark; one pale spot situated beyond the middle of the costa at junction with subcostal vein; second pale spot situated at half the distance between the first pale spot and apex of the wing; third pale spot situated just before apex of the wing. First longitudinal vein with base pale; two pale spots beyond the junction with subcostal vein; pale spots also present opposite those on the costa. Other pale spots very small, consisting of a few pale scales situated at the cross-veins, at the bases of the anterior and posterior fork-cells, also at the distal ends of third vein and each branch of the fourth and fifth veins. With a high power a very few pale

scales can be seen on the lower branch of the fifth vein towards the base. The pale fringe spot at the apex of the wing separated from the third costal spot by a small black fringe spot between the ends of the branches of the second vein; remainder of fringe from the third vein to the base all dark, except for indistinct pale fringe spots opposite the branches of the fifth vein. The base of the posterior fork-cell nearer to the apex of the wing than that of the anterior fork-cell; the posterior fork-cell shorter than the anterior. The supernumerary cross-vein slightly nearer to the apex of the wing than the mid cross-vein, but only by about its own thickness; the posterior cross-vein about its own length nearer to the base of the wing than the mid cross-vein. *Abdomen* with the integument dark brown, almost black; no scales, hairs brown.

♂. With the natural exception of the essential sexual differences the male coincides with the above description. The terminal segment of the male palpi has the apex pale and another inconspicuous pale band midway.

Dimensions: length of body from front of head to tip of abdomen, 4 mm.; length of wing, 4 mm.

SOUTHERN RHODESIA: Shamva, May–August, 1927, 9 ♂♂, 8 ♀♀, taken in native huts and drains near Mazoe River, and 1 ♂ and 1 ♀ from the Fungwi Reserve, July, 1928 (*H.S.L.*).

Type ♂ and ♀ presented to British Museum.

The wing of this mosquito closely resembles that of the female of *Anopheles smithi*, Theobald, but wings of males captured at the same time and place as the females are identical in the arrangement of the scales; also the apical segment of the female palpi is not dark but broadly pale-banded. From true *Anopheles funestus* this variety differs in its larger size and in the entirely dark veins, and from *Anopheles funestus* var. *bisignatus*, Grünberg, in the absence of a pale costal spot before the middle of the wing.

This mosquito, while of distinct appearance through its dark coloration and large size, possesses in the male hypopygium no structural differences which would separate it from *Anopheles funestus*. It has, therefore, been thought advisable to regard it as of varietal rather than specific rank.

PRELIMINARY NOTE ON LEAF-CRINKLE OF COTTON IN THE GEZIRA AREA, SUDAN.

By T. W. KIRKPATRICK, M.A., Dipl. Agric. (Cantab.).
Assistant Entomologist, Wellcome Tropical Research Laboratories.

Owing to the wide divergences of opinion at present current among those in the Sudan who are interested in leaf-crinkle of cotton, it is thought that the present paper, incomplete as it is, may be of some value in indicating what little knowledge has so far been obtained by observations and direct controlled experiments, and in outlining the more obvious and important directions in which further investigations should proceed.

Although the name 'leaf-curl' has been used by many in the Sudan when referring to this disease, it is proposed that the term 'leaf-crinkle' be adopted instead, firstly, because this term is far more descriptive—badly affected leaves are often found which are not 'curled' at all,—and secondly because the symptoms are quite distinct from those of the disease described by Cook¹ as 'hybosis, or leaf curl'; although they resemble in many (but not all) respects those of the disease of cotton in Nigeria which Jones & Mason² refer to as leaf-curl.

Description of the Symptoms of Leaf-Crinkle.

Briefly, the first visible signs of attack on Sakellaridis cotton appear to be as follows. A leaf that is already fully grown never contracts crinkle, but a partly grown leaf may develop a thickening of the lower surface of the smaller veins. Such thickening starts at a number of points, which gradually tend to join up, until all the veins are affected, or the main veins may remain normal, or sometimes only part of the leaf area becomes crinkly, some of it remaining unaffected. Leaves younger than that on which the crinkle made its first appearance are usually affected all over. Frequently, however, the symptoms first appear on the very young leaves, the just older, partly grown ones developing normally.

If a crinkly leaf is viewed from beneath against the light, it will be seen that these thickened veins are darker green than the rest of the leaf and consequently opaque, instead of being translucent as are the veins of a normal leaf. This character appears to be the best criterion for the presence or absence of leaf-crinkle, especially when it is necessary to decide if the disease is present in a mild form on a young leaf or, an epicalyx, as normally these are often somewhat rugose in appearance, but without thickened and darkened areas on the veins.

The upper surface of the leaf may be almost normal, though as a rule the veins are somewhat sunken, thus bringing into relief the areas between the veins and producing a markedly wrinkled appearance.

The first symptoms of crinkle have been noticed to appear on the first true leaf (but never on the cotyledons) both on plants in the field infected naturally and on those in the laboratory which had been artificially infected. When an older plant that already has flower buds contracts the disease, it is often the epicalices of the buds that show the first signs of thickening of the veins.

In the majority of cases such crinkling of the leaves—and epicalices if present—is the only symptom manifested, though the degree of crinkle varies greatly in different plants. There is little or no curling of the leaves noticeable. In some plants, however, at a variable time after the first infection was visible, the symptoms become greatly intensified. The new leaves produced are small, exceedingly crinkly, and curled

at the edges, either upward or downward. Not infrequently oval cup-like foliar growths are produced on the greatly thickened lower sides of the primary veins. One such growth has been observed over ten millimetres long and five broad, but mostly they are smaller than this. The primary stem of the plant often tends to grow taller than normal, the internodes being elongated and irregularly curved; but sometimes the whole plant is stunted in growth. All parts of a badly affected plant are very brittle and readily broken.

There is not, however, any definite distinction between "mild" and "severe" crinkle, and plants showing every range of symptoms, from those in which the disease can only be diagnosed if a leaf is viewed against the light, to those in which the whole plant is abnormal and distorted almost beyond recognition as a cotton plant, can be found in the same field.

The symptoms of leaf-crinkle have also been observed on *Bamia* (*Hibiscus esculentus*, L.) and *Til* (*H. cannabinus*, L.).

No attempt has been made by the present writer to study the physiology or biochemistry of crinkly cotton plants, as it is understood that this is being done by other workers.

Plants which have contracted crinkle to a slight or moderate degree not infrequently recover, at any rate apparently, to a marked extent. New growth may be to all outward appearances normal, though usually—perhaps always—slight traces of thickened veins are present on such leaves. It is not yet known whether such plants still retain the disease in an active form.

No case of recovery has yet been observed in a very badly affected plant.

Effects of Mutilation of the Plant on the Symptoms of Leaf-Crinkle.

If a plant which has leaf-crinkle, even mildly, is mutilated, *e.g.*, by topping, the symptoms are usually very greatly intensified; it also seems that mutilation, provided that the plant has been infected, in some way shortens the period during which the disease is latent and causes the symptoms to be manifested sooner than would otherwise have been the case.

On 30th October 1929, a number of plants in one row were topped, the next row to it being kept as a control. There were then very few crinkly plants in the plot used, none of the topped plants and only one (=less than 1 per cent.) of the control plants showed any signs of the disease. On 10th November 1929, of the topped plants 29 per cent. were crinkly, and of the un-topped ones only 7 per cent. On 22nd November 1929, 33 per cent. of the topped plants were crinkly, *i.e.*, only a slight further increase in 12 days, but the un-topped plants now showed symptoms to the extent of 33.6 per cent., *i.e.*, almost exactly the same proportion as the topped ones.

This also indicates that the condition is not actually produced by mutilation—a suggestion which had been put forward in certain quarters owing to the greater intensity of crinkle on the edges of cotton fields, where the plants are very frequently damaged by animals. It may also be mentioned in this connection that a large number of cotton plants have been grown in insect-proof cages, none of which showed any symptoms of crinkle; ten of these were topped and pruned in various ways, but the new growth was in every case perfectly normal.

Although the new growth from a topped crinkly plant very often, as has been said, shows intensified crinkle, yet this severe form is not dependent on mutilation, as there are two instances of cotton plants grown in water cultures, artificially infected by *Aleurodids* but otherwise completely protected from all injury, which developed the symptoms to as great a degree as has ever been observed in the field.

The Spread of Leaf-Crinkle in the Gezira.

From the statements of those who have been resident in the Gezira for a number of years, it appears probable that leaf-crinkle has been present for a long time; it was not, however, until the 1927-1928 season that sufficient crinkly plants were observed for attention to be drawn to them.³

During the 1928-1929 season (the first in which the writer was working in the Gezira) the disease appeared during October, apparently considerably earlier than it had been noticed formerly, and in some places spread rapidly until 90-95 per cent. of the plants were affected, though mostly not to a severe degree. Pressure of other work was responsible for little more than casual observations being made during this season, but considerable interest was aroused in the disease.

During the cotton season of 1929-1930, the development of the symptoms of leaf-crinkle in the Gezira was followed as carefully as time would permit. Two plots on the Gezira Research Farm, each containing between 1,500 and 2,000 plants, were examined weekly and the number of infected plants noted. The two plots were situated about 300 yards apart, and both were sown at the normal time of sowing the main crop, *i.e.*, 15th August 1929. Plot I was on rather poor land that had not previously been under irrigation; it received a dressing of 200 lb. of sulphate of ammonia per feddan.* Plot II was on rather better land that had been under cultivation for some years; it received no manure. On account of black-arm disease, among other causes, the growth of the plants was distinctly below average on both plots.

In addition counts were made at necessarily longer and irregular intervals of the progress of infection on six other smaller plots (200-400 plants each) in various parts of the Gezira.

The rapid and general increase in the appearance of crinkle on these plots during October and November is shown in Table I.

It may be noted that although the rates of increase are approximately similar in each locality, there is for any given percentage of infection a difference of about a month between one of the localities in Tebub block and the one in Dolga block; also there is a fortnight's difference between the two plots on the Gezira Research Farm, which, as has been said, were only 300 yards apart, and also between the two plots in Tebub block, which were about two miles apart.

The progress of the appearance of leaf-crinkle was more or less similar to that in these selected localities over the whole of the Gezira area, with the exception of the greater part of the area in the west and north-west which had not previously been under irrigation. It was unfortunately impossible to make any regular counts of the incidence of crinkle in these blocks, but a number of approximate estimations of the percentage of plants affected was made in various places from time to time.

Roughly, the progress of the disease in these new blocks was as follows. In the south of Efeina and Wad el Bur blocks, which are situated at the southern end of the new area, leaf-crinkle spread in very much the same way as over the rest of the Gezira. Over the northern end of these two blocks, and over very nearly the whole of the five new blocks to the north of them, the first crinkly plants were later in appearing, the rate of increase was slow, and the percentage of infected plants has nowhere as yet (March 1930) reached 90-100 per cent. as it has elsewhere; in most places it is still 10-20 per cent. or less. The cotton in these blocks where the leaf-crinkle is comparatively slight is, generally speaking, more vigorous and a better crop than that in the rest of the Gezira, apart altogether from the effects of leaf-crinkle.

* A feddan = 1.038 acres.

Throughout the Gezira during the 1929-1930 season the greater number of crinkly plants only showed the symptoms to a mild or moderate degree; it is, however, thought that the number of more severely affected plants was somewhat greater than in the previous year.

TABLE I.

The Rate of Increase of Leaf-Crinkle in various Localities in the Gezira during October and November, 1929.

Locality.		October.				November.			
Gezira Research Farm Plot I	...	—	13th 6 per cent.	20th 14 per cent.	27th 20 per cent.	3rd 48 per cent.	10th 71 per cent.	17th 88 per cent.	24th 94 per cent.
Gezira Research Farm Plot II	...	10th 2 per cent.	7th 4 per cent.	27th 10 per cent.	31st 14 per cent.	7th 26 per cent.	13th 35 per cent.	20th 55 per cent.	27th 79 per cent.
Tebub Block Plot I	...	—	—	21st 28 per cent.	—	4th 81 per cent.	—	21st 94 per cent.	—
Tebub Block Plot II	...	—	—	21st 2 per cent.	—	4th 26 per cent.	—	21st 79 per cent.	—
Tayiba Block		—	11th 6 per cent.	—	26th 36 per cent.	7th 73 per cent.	—	—	30th 95 per cent.
Wad Sulfab Block		—	15th 1 per cent.	—	29th 6 per cent.	—	—	—	30th 70 per cent.
Dolga Block	...	—	15th 1 per cent.	—	29th 2 per cent.	—	—	—	30th 56 per cent.
Um Degarsi Block		—	15th Nil	—	29th 6 per cent.	—	—	—	30th 86 per cent.

An estimation of the intensity of the disease was made on 1,200 plants in Plot I on the Gezira Research Farm on 11th November 1929. Those plants which showed the symptoms were classified in four categories: (1) Very mild, symptoms only just visible; (2) mild, but plants quite noticeably crinkly; (3) moderate, most leaves very crinkly, but growth of plant otherwise normal; (4) severe, leaves very crinkly and curled, and the internodes distorted. The results are shown in Table II.

It is thus seen that a plant is capable of developing the disease in a severe form within three weeks or possibly less from the time when the symptoms were first visible, a fact which has been subsequently borne out by observations on plants artificially infected.

It appears from observations on the Gezira Research Farm that the date of sowing has considerable bearing on the percentage of plants that become infected with leaf-crinkle, and also on the time, relative to the date of sowing, of the first appearance of the disease.

TABLE II.
The Intensity of Leaf-Crinkle on 1,200 Cotton Plants on the Gezira Research Farm on 11th November 1929.

Date on which the plants first showed symptoms of Leaf-Crinkle.	On or before 13.x.29 (96 plants)	14.x—20.x (138 plants)	21.x—27.x (113 plants)	28.x—3.xi (492 plants)	4.xi—10.xi (374 plants)	TOTAL (13.x—10.xi) (1,213 plants)
Degree of intensity of symptoms ...	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Percentage of plants in each category ...	11 43 32 14	12 42 43 3	14 51 31 4	28 57 15 0	60 38 2 0	33 48 17 2

TABLE III.
Variation in the Appearance of Leaf-Crinkle on the Gezira Research Farm, according to the Date of Sowing.

Date of Sowing.	Approximate date, and number of days from sowing, when Leaf-Crinkle			
	First appeared.	Reached 25 per cent.	Reached 50 per cent.	Reached 75 per cent.
15.viii.29	5.x.29=51 days	22.x.29=68 days	30.x.29=76 days	8.xi.29=85 days
5.x.29	7.xi.29=33 days	15.xii.29 71 days	18.i.30 105 days	5.iii.30=151 days
22.x.29	17.xi.29=26 days	19.xii.29=58 days	19.i.30=89 days	7.iii.30=136 days
21.xi.29	13.xii.29=22 days	[28 per cent. on 11.iii.30, =110 days]	—	—
29.xii.29	?	[8 per cent. on 11.iii.30, =72 days]	—	—

A number of contiguous plots of cotton were sown at intervals between 15th August and 29th December 1929. Time only permitted of regular counts of the percentage of leaf-crinkle being made on three of them, but the following observations (Table III) appear to be worth recording for the sake of future comparison, though it is not proposed to offer any comments at the moment.

Effects of Leaf-Crinkle on the Cotton Plant.

Practically nothing is as yet known with certainty about this most important question. From general observations it would appear that a mild or even moderate attack causes no noticeable damage to the crop; at the same time there can be no doubt that a plant which has contracted the disease in a severe form is rendered partly or perhaps in some cases completely sterile.

It is not proposed to give here the detailed results of the admittedly insufficient experiments which are all that time has hitherto permitted, but there is some evidence that leaf-crinkle not only tends to cause a reduction in the number of bolls set per plant, but possibly also a reduction in the number of seeds per boll.

Experiments in Mechanical Transmission of Leaf-Crinkle.

The symptoms of leaf-crinkle are very similar to those of certain "virus diseases" of various plants. Attempts were therefore made to transmit the infection by mechanical means, and by the more likely insect pests which it was thought might possibly be capable of carrying the infection.

It has so far been found impossible to transmit the disease by any of the following methods:—

(1) Scratch inoculations on either old leaves, young leaves or stems, or all three together on the same plant, by means of a needle scratch through a drop of inoculum composed of juice expressed from fresh leaves of crinkly plants; both cotton and *bamia* plants have been tried.

(2) Rubbing the leaves of healthy plants with crinkly leaves until a lesion is produced.

(3) Insertion of fresh crinkly tissue into the stems of healthy plants, the wound being immediately sealed up with wax.

No grafting experiments that can be considered critical and worth recording have as yet been carried out.

Insect Transmission.

The following general evidence that leaf-crinkle is transmitted by insects has been obtained.

(1) Upwards of 100 cotton plants were grown under muslin cages intended to protect them from all insects; some of these, however, were attacked by thrips (*Heliethrips indicus*, Bagnall), as the mesh of the muslin was not fine enough to exclude these insects, and a few by Aphids (*Aphis gossypii*, Glover), which were presumably carried underground by ants. None of these plants contracted leaf-crinkle, though plants from similar seed growing in close proximity to the cages did so.

(2) Forty cotton plants were grown in large pots on the roof of the laboratory and protected by fine muslin from all insects (except thrips, which found their way into two of the pots). When three weeks old, twenty-one of these plants were taken to a cotton field, placed among crinkly plants, and the protective cover removed.

These developed the disease as follows :—

After 16 days, 1 showed symptoms of crinkle.

„	24	„	6	„	„	„
„	38	„	17	„	„	„
„	87	„	all	„	„	„

None of the remaining nineteen plants which were kept protected contracted the disease.

Prima facie, the most likely insects to be vectors of the disease seemed to be JASSIDAE or ALEURODIDAE. Other possibilities investigated have been thrips, Aphids and flea-beetles, though leaf-crinkle has appeared where no thrips or Aphids could be found, and it was unlikely, though not impossible, that a biting insect such as a flea-beetle would carry the infection.

The only member of the family JASSIDAE (*sensu lato*) that occurs commonly in the Gezira, and the only one with which transmission experiments have been attempted, is one that has been identified as *Empoasca facialis*, Jac. Other species occur, but in such comparatively insignificant numbers as to make it impossible that they could be the principal vector of leaf-crinkle.

Experiments with Jassids.

The following transmission experiments* were made with *Empoasca facialis*.

(1) Forty cotton plants were grown in large pots on the roof of the laboratory, two or four plants in each pot. Some of these were covered with muslin, others were left exposed; the only insects which were ever observed on the exposed plants on the roof were thrips and a few Aleurodids. On twenty of these plants Jassids were enclosed, the controls to each experiment being the other plant, or two plants, in the same pot. The method used was to collect adult and immature Jassids from a cotton field where there was a high percentage of crinkle, only taking those actually on crinkly plants. In most cases these were then enclosed in pill-boxes on a crinkly plant outside the laboratory for from four to seven days before being used. They were then enclosed on the underside of a leaf of the plant to be experimented on, in a glass-bottomed pill-box fastened on with a clip. From four to twenty Jassids were used on each plant; they lived in this manner perfectly satisfactorily for a fortnight or more, and fed readily. When more than six or eight were enclosed on one leaf it was necessary to shift them occasionally to give them a fresh supply of food. Two only out of the forty plants developed crinkle, both these being in the same pot—one of those which was not protected by muslin; one of these plants had had eight Jassids enclosed on it, the other being the control plant which had had none.

(2) A large number of plants were grown in small pots which were covered with a lamp-glass and muslin. These plants grew rather feebly and made very slow progress, especially during the cold weather, owing presumably to the very low soil temperature due to the evaporation from the pots. Of forty-five plants on which Jassids that had previously fed on crinkly cotton were placed, one developed crinkle. This plant had been accidentally left uncovered for three days after the appearance of the seedling, and it is therefore possible that other insects may have fed on it at this stage. Of thirty-four similar plants without any insects none developed leaf-crinkle.

It may also be added that leaf-crinkle has appeared on young late-sown cotton growing on the Gezira Research Farm, on which no Jassids could be found, and that

* It should be mentioned that the cotton seed used in all the experiments detailed in this paper was from the same source, viz., the Tokar crop of 1928-1929.

although *Empoasca facialis* occurs all over the Gezira area on cotton sown at the normal time, there is no apparent correlation between the abundance of these insects and the amount of leaf-crinkle.

It is consequently concluded that *Empoasca facialis* is certainly not mainly responsible for carrying leaf-crinkle, and it is extremely doubtful if it is ever capable of being a vector.

It was therefore with some little surprise that the writer read an article in "*Nature*" No. 3147, 22nd February 1930, entitled "Cotton in Africa," being an account of the report of the executive committee of the Empire Cotton Growing Corporation to the meeting of the administrative council, held in Manchester on 21st January 1930. The following is quoted from this article: "The Sudan is now producing an increasing quantity of cotton which is almost indistinguishable from the best qualities of long staple Egyptian cotton. Recently the disease known as leaf curl has been attacking the crops in this locality, and there is evidence that the jassid insect is responsible for spreading the contagion. The Corporation is now considering the desirability of breeding jassid-resistant strains in the Sudan."

It is not known that any entomologist or other scientist apart from the present writer has made any experiments on the transmission of leaf-crinkle by Jassids or other insects in the Gezira area (which is by far the most important long-staple producing area in the Sudan), and it is not known what the alleged "evidence that the jassid insect is responsible for spreading the contagion" consists of. In view of the positive evidence of the transmission of the disease by ALEURODIDAE which is adduced below, it would appear that the Empire Cotton Growing Corporation would be somewhat premature in breeding Jassid-resistant strains of cotton as a means of controlling leaf-crinkle in the Gezira.

Transmission Experiments with Aleurodids.

Of thirty-two plants, in small pots covered with a lamp-glass and muslin, on which were placed white-flies taken from a cotton field where the percentage of crinkle was high, eleven developed the symptoms in a period varying from thirty-four to sixty-two days. The controls to these were the thirty-four plants grown under similar conditions and used also as controls to the attempted inoculations by Jassids, none of which, as has been said, contracted crinkle.

The comparatively small number of successful inoculations (about one in three) and the long incubation period before the symptoms were manifested are thought to be due to the very slow growth of the plants in these pots. A similar difficulty in infecting badly growing plants has been found by Smith working on potato virus diseases, ⁴ p. 80.

As it had been suggested that leaf-crinkle might possibly be a deficiency disease, or else carried in the soil or in the water, it was thought that more critical experiments on transmission by white-flies could be carried out on plants growing in water-culture solutions.

The formula used has been that described by Percival.⁵ It may be of interest to state that the solutions have not been aerated, nor have they been changed weekly, as is recommended in all text-books on Plant Physiology; furthermore, many of them, including those which have made the best growth, have been kept out of doors in almost full sunlight, where the temperature of the water has sometimes exceeded 50° C. on warm days, and that of the air under the glass covers protecting the plants has reached 55° C. In spite of the neglect of these precautions, the cotton plants have in most cases grown satisfactorily for a period of some eight to ten weeks or more, especially in the larger jars.

The seeds were germinated under cover in the laboratory, and when the radicles were about 5 centimetres long they were transferred to the culture jars and covered with lamp-glasses and fine muslin. The white-flies used were collected from cotton in places where the percentage of leaf-crinkle was 90 to 100. The figures given of the numbers of white-flies enclosed on each plant are very rough approximations. The controls to each experiment were treated in an exactly similar way except for the absence of all insects.

The following are the experiments which have so far been carried out.

(1) Two seedlings transferred to four-litre jars on 2.i.30. On 7.i.30 about 50 white-flies inserted on one plant. This plant showed definite traces of crinkle on a new leaf on 8.ii.30, *i.e.*, after 32 days. About 15.ii.30 the lower leaves were mostly shed and a number of new leaves were formed, which were exceedingly crinkly and curled. On 12.iii.30 the plant was about 25 centimetres high, but the stem very much distorted; it had about 25 leaves, the largest of which was about 4 centimetres in diameter, all showing crinkle in its most severe form, and many with foliar outgrowths on the lower side of the veins—the two largest of these were 6 millimetres in length.

The control plant has grown normally; on 12.iii.30 its main stem was about 45 centimetres in height; it bore about 25 leaves, all of which were without trace of crinkle, and the largest of them over 10 centimetres in diameter.

(2) Eight seedlings transferred to 700 cc. jars on 10.i.30. On 15.i.30 about 150–200 white-flies were inserted on each of four of the plants. These grew as follows:—

(a) [*Note.*—Two or three thrips were accidentally inserted on to this plant, they did not, however, breed.] Definite symptoms of crinkle appeared on 9.ii.30, *i.e.*, after 25 days. By 1.iii.30 the new growth was affected with the severe type, and a few of the leaves produced small foliar outgrowths. The plant died on 9.iii.30.

(b) Probable crinkle appeared on the second leaf on 30.i.30, *i.e.*, after 15 days; this was quite definite by 3.ii.30. The plant was rather yellow and made slow progress; the symptoms were never very severe and no foliar outgrowths were produced, nor was the stem distorted. The plant died on 22.ii.30.

(c) Crinkle first appeared on the first leaf on 29.i.30, *i.e.*, after 14 days. Only three leaves were produced, all of which were crinkly, and the plant died on 20.ii.30.

(d) This plant first showed symptoms of crinkle on 5.ii.30, *i.e.*, after 21 days. Although rather yellow, it grew fairly well, all the subsequent leaves being crinkly, but it died suddenly on 22.ii.30.

It is thought that too many white-flies were placed on these plants, and that direct damage by them may have been responsible for the poor growth of the plants.

The four control plants grew as follows:—

(a) Entirely normally; on 12.iii.30 it was about 28 centimetres high, with large healthy green leaves.

(b) This plant grew rather badly, owing to a slight “damping off” on the hypocotyl. About 10.ii.30 the leaves turned yellow, and the plant died on 19.ii.30. No trace of crinkle was present.

(c) Almost indistinguishable from (a), though slightly taller and lankier.

(d) This plant also suffered from “damping off” on the hypocotyl, and though new green and perfectly sound leaves began to form about 14.ii.30, it did not recover and died on 18.ii.30.

(3) Three seedlings transferred to 4-litre jars on 2.ii.30. One of these was left uncovered.

On 6.ii.30 a large number (about 200) of white-flies was placed on one of the covered plants. This showed possible symptoms of crinkle on 19.ii.30, *i.e.*, after 13 days, and very definite symptoms by 23.ii.30. This plant has grown very slowly, the earlier leaves have been shed, and on 12.iii.30 it possessed only three fully formed leaves, all of which were definitely but not severely crinkly.

The control plant grew well and on 12.iii.30 was a strong healthy plant over 35 centimetres high, with large bright green leaves and no trace of leaf-crinkle.

The plant which was left uncovered was observed to have white-flies feeding on it from the day after the first leaf appeared; not more than twelve were ever seen on it at one time. Leaf-crinkle appeared on 24.ii.30, and the subsequent leaves showed the symptoms in a marked form. By 10.iii.30 the stem and leaf-petioles were beginning to show signs of distortion.

(4) Six seedlings transferred to 700 cc. jars on 3.ii.30. These were kept in the shade. On 5.ii.30 (*i.e.*, before the cotyledons had fully opened) about 50–100 white-flies were enclosed on each of three of them (*a*, *b*, and *c*) the other three (*A*, *B*, and *C*) were kept as controls.

(*a*) First showed the symptoms on the third leaf on 19.ii.30. On 12.iii.30 it was a tall lanky plant, 40 centimetres high, with few leaves, which all showed very severe thickening of the veins but no appreciable stunting or curling.

(*b*) Developed crinkle on the second leaf also on 19.ii.30. On 12.iii.30 it was similar in appearance to (*a*), though not quite so tall, and the two newest leaves were curled as well as crinkly.

(*c*) Grew rather slowly; it produced a long stem, but very few leaves. On 4.iii.30 no symptoms of leaf-crinkle had appeared, and the growing point was then cut off; new growth was produced which by 14.iii.30 was definitely crinkly.

Of the three control plants, *A* was infected with "damping off" and died on 16.ii.30.

B grew normally and well, but was unfortunately blown over in a gale on 23.ii.30.

C was a normal healthy plant; on 4.iii.30 its growing point was also removed, and the new growth that appeared was entirely free from the symptoms of leaf-crinkle.

A further series of similar water-culture experiments has been started with varying and mostly smaller numbers of white-flies, and though some of these have already developed the symptoms of leaf-crinkle, it is as yet too early to comment on the results.

It is thus seen that of nine plants grown in water-cultures on which white-flies from crinkly cotton were placed, eight developed leaf-crinkle after a lapse of from 13 to 32 days, the symptoms being manifested in varying degrees, but in two cases to as severe an extent as has ever been observed in the field. The remaining one had not developed the symptoms in 27 days, but did so on the new growth 10 days after the removal of its growing point. Of eight control plants (excluding the one that died early from "damping off") which were treated in exactly the same way except for the absence of white-flies, not one developed the slightest trace of leaf-crinkle.

It is therefore concluded that white-flies are the main, and probably the only, vectors of the disease. It may be mentioned that a number of transmission experiments with flea-beetles (*Nisotra uniforma*, Jac.) all gave negative results, as was probably to be expected. The only likely possibility that remains, which is at present being tested, is that Aphids may be subsidiary carriers. In any case they could not be responsible for the main spread of the disease, as they are practically non-existent on cotton in the Gezira until late in the season.

Points needing Investigation.

The most important questions in connection with the transmission of leaf-crinkle which remain to be elucidated, on some of which work has already been begun, are:—

(1) Whether the larva of the white-fly must have fed on a crinkly plant, or the larva and the adult, or the adult only, before it is capable of carrying the infection.

(2) Whether a single or a few white-flies can infect a plant—all experiments to date having been done with fairly large numbers.

(3) What influences the severity of the disease? *e.g.*, a larger or smaller dose of infection, or the condition of the plant, or other factors.

(4) Information about the incubation period of the disease (*a*) in the white-fly ; (*b*) in the plant.

(5) How the disease is carried over from one season to the next.

(6) As much information as possible on the bionomics of white-flies, especially as to their habits during the months of June to August, when there is no cotton in the Gezira.

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A NEW FORM OF APPARATUS FOR PHOTOGRAPHING INSECTS.

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(PLATES V & VI.)

In the course of some six years' work, the apparatus here described has been progressively evolved from my original apparatus, which has already been dealt with in this journal (xv, p. 49).

The special features of the previous apparatus, namely, (1) the simultaneous illumination of the object from above and below, and (2) the combination of a vertical focussing screen with a horizontal stage by use of a reflecting prism, have been retained throughout. It was found, however, that although the focal length of the camera lens originally employed (namely, 3 inches) gave sufficient depth of focus to produce a perfectly sharp picture of a mosquito, an increased focal length was desirable when photographs of larger insects were being made. In successive modifications of the apparatus, therefore, the focal length has been continually increased; the distance between the focussing screen and the object becoming correspondingly greater. In the present form of the apparatus the maximum distance from the focussing screen to the object is 5 ft. 6 ins., and lenses up to 6 inches focal length are employed. Direct photographs up to whole plate size ($8\frac{1}{2}$ by $6\frac{1}{2}$) can be taken.

This lengthening of the apparatus has necessitated the introduction of various "distant control" devices, to enable the operator to observe the image of the object on the focussing screen while altering its size, focus, position and illumination. By angularly displacing the object-carrying stage between successive exposures, stereoscopic photographs of any given "perspective" can be produced, as will be described later.

In this apparatus (Pl. V, figs. 1 & 2), the focussing screen is fixed to a table which also carries a pair of longitudinal guide rails (R_1, R_2). Along these rails travels a wheeled chassis (C), movable to and fro by means of an endless chain actuated by the handwheel (U). This chassis carries: (1) a fixed carriage (F) supporting the lens housing (H); and (2) a tilting carriage (T), upon which is mounted the object-carrying stage (S). The object, which rests upon a glass disc, is illuminated (*a*) from above, by the adjustable lamps illustrated; and (*b*) from below, by a lamp and condenser (not shown) mounted on the chassis within the tilting carriage. The prism (P) fixed directly above the stage (S) reflects the rays from the illuminated object into the camera lens, whence they travel to the focussing screen through the focussing bellows (A) and the extension bellows (B). When the intensities of the downward and upward illuminations are correctly proportioned, the focussed image of any insect appears upon a "shadowless" background, with the body markings and wing venation both clearly defined.

Focussing is effected by the handwheel (V) which rotates a square-sectioned shaft (J) upon which slides one of a pair of bevel wheels (K). The companion bevel wheel actuates (through a worm gear, G) a pinion which engages with a rack fixed to the lens housing (H). Any rotation of the shaft (J) therefore causes the lens housing to move backwards or forwards along the carriage (F); thus varying the distance between the camera lens and the object.

The glass disc which carries the object can be rotated about its own axis by means of the flexible shaft (M) or moved transversely or longitudinally within the stage (S) by means of the Bowden wires ($N_1, 2$). The flexible shaft and the two Bowden wires are actuated by the three small handwheels ($W_1, 2, 3$).

When an insect is being photographed it is usually supported on the point of a headless pin $1/100$ inch thick, which passes loosely through a $1/64$ inch hole in the glass disc.

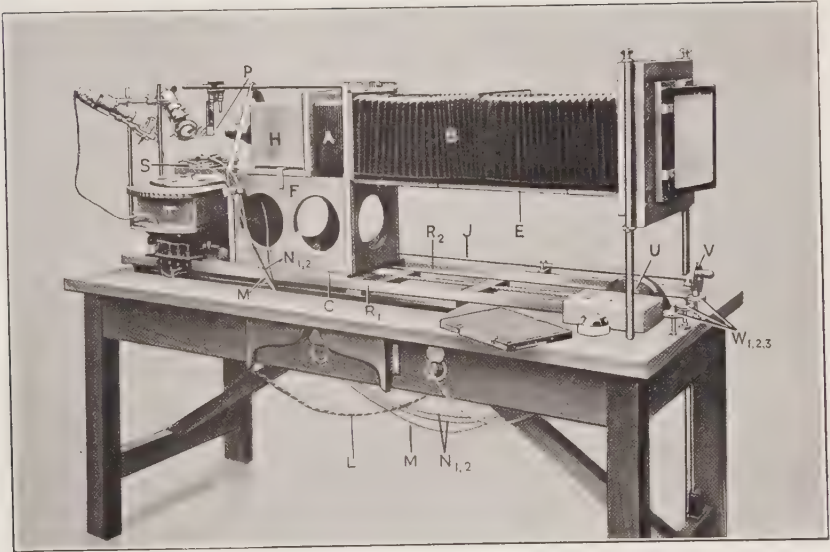
Current for the various illuminating lamps is supplied through the multiple cable (L) leading from the switchboard seen alongside the handwheel (U).

The distance between the camera lens and the focussing screen can be varied from 5 ft. 3 ins. to 2 ft. 4 ins. The extension bellows (B) rest upon a pair of telescopic tubes, one of which is shown (E).

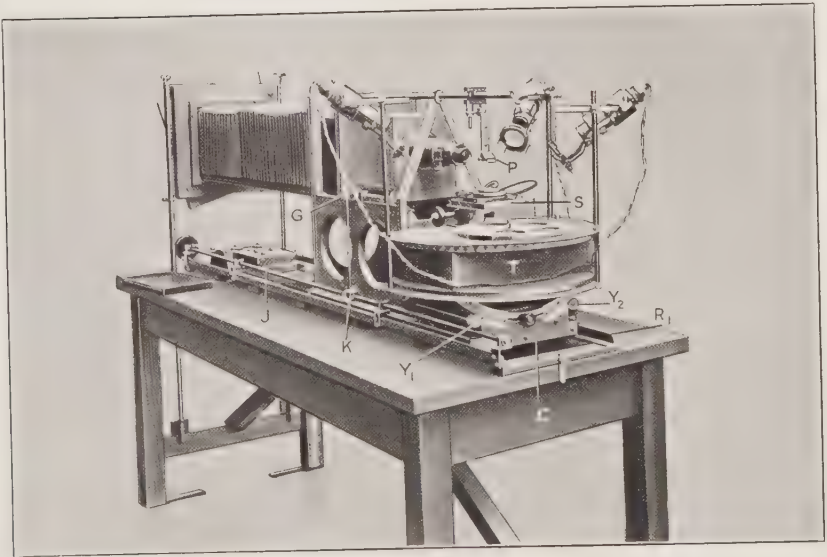
On the base of the tilting carriage (T) there are two circular arcs, the centres of which are co-axial with the object to be photographed. Each arc is supported on a pair of grooved wheels, one pair of which (Y_1, Y_2) is shown in Plate V, fig. 2. The carriage (T) may therefore be tilted through any desired angle; the object on the stage (S) being thus turned through the same angle without being displaced laterally. By taking two successive negatives with the tilting carriage (and therefore the stage S) inclined equally in opposite directions, stereoscopic photographs of any degree of perspective may readily be obtained.

In photographing specimens mounted on microscope slides which require illumination by transmitted light only, two methods of procedure are available. In one, the microscope slide is placed upon the stage (S) and illuminated from below only. In the other, the prism (P) is removed and replaced by an ordinary microscope stage, which carries the slide to be photographed; axial illumination being provided by one of the adjustable lamps.

The accompanying illustration of a mosquito (Pl. VI) is reproduced from an untouched negative taken with this apparatus.



1.



2.



Female of the arboreal mosquito *Orthopodomyia pulchripalpis*, Rondani. $\times 6.3$.

LOCUST-HOPPERS AND BIRDS IN EAST AFRICA.

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During the early part of 1929, a specially severe infestation of locusts occurred in the northern provinces of Tanganyika Territory, an extension of the plague already felt in Kenya. Laying was known to have taken place more or less continuously over the drier country all the way from Longido, west of Kilimanjaro, to the West Usambara Mountains. Successive broods of young locusts had to be dealt with; and in the same area it was possible to see newly hatched hoppers and insects almost full-grown and able to fly. An ample supply of extra food was therefore provided for any birds that might care to avail themselves of it, except the smallest, and certain specialists such as the Hirundines. I was anxious to get some idea of how the birds would react to these abnormal food-conditions, and by the kindness of Dr. and Mrs. R. R. Le G. Worsley, the former of whom was in charge of a sector of the locust campaign, I was able during the first week of June 1929 to make observations in a very heavily infested area between the Middle Pangani River and the South Pare Mountains. I have also to thank the Director E.A.A.R.S. for certain facilities in this connection.

The base on the Tanga-Moshi Railway for this sector was Hedaru Station, only a couple of miles south of the bare rocky wall of the Pares. The intervening ground is occupied by a dense growth of thorn scrub that extends with little interruption across the railway to the Pangani River about eighteen miles further south. The area between the railway and the river forms a game reserve and is quite waterless. It is gently rolling country, except that near the river it rises into hill-clumps about a thousand feet high, steeply scarped towards the river and densely covered with thorn trees. Along most of the valley the thorns are divided from the river-meadows ("mbuga") by a strip of perfectly bare ground, in places a quarter of a mile wide, which is possibly too salted to permit the growth of vegetation, whether xerophytic or not. From the tracks running between the "mbuga" and the thorns it is possible to form some idea of the great numbers of game that lie up in their depths during the hours of daylight. There is literally not a square foot of the ground along the edge of the thorns that is not pitted with tracks, among which the formidable hoof-marks of the buffalo are most prominent. The river itself winds through a beautiful "mbuga," a meadow-like strip of flat country about three miles wide, in which its course is marked by narrow belts of tall acacia trees. In one place, near the settlement marked Kwa Lua on the imperfect maps of the region, the whole of the "mbuga" lies on the south of the river, and five yards from the north bank typical thornbush exists. Beyond the "mbuga" rises the rolling thorn-clad country of the Masai Reserve, very similar to that traversed on the way from Hedaru.

I was informed that in most years the "mbuga" is a swamp in June, but on this occasion the rains had been so short that the going was generally good in the meadows although the grass was still bright green. Human population was scanty and game correspondingly plentiful. There was a village of a dozen people at Muhesa, where the main camp was pitched, nothing for at least ten miles to the east, and the villages of Mavungwe nearly twenty miles to the west. By Dr. Worsley's kindness I was able to visit all these points, and I was therefore able to get an idea of conditions over a T-shaped tract of country of which Muhesa was the junction and the cross-line the Pangani Valley.

Hoppers were swarming at Hedaru on the occasions of both my arrival and departure. Dense patches of them occurred at intervals on the desert track, where birds appeared to exist in very small numbers all the way across to the Pangani. The

immediate neighbourhood of Muhesa had been cleared of hoppers before my arrival, but a few miles to the east, on the Kwa Lua reach where the thorn-desert came right down to the water on the north side, the dry bank was seething with young hoppers so closely packed that the ground and the leafless twigs of the undergrowth took on their yellow and black coloration. The hoppers did not seem to occur on the "mbuga" itself, nor much on the extremely dry and sandy stretch between Muhesa and Mavungwe. Round the latter place they were very plentiful again in dried-up grass, and when this area of infestation was first discovered a large proportion of them were in the last, "pink," stage and crawling up the bushes to dry their wings preparatory to flight. What hoppers there might be in the depths of the thorn bush off the track and away from the river, nobody could tell because the scouts were too terrified of the buffaloes to penetrate it; and much the same uncertainty existed with regard to the land across the river, where the information given by the Masai was coloured by their anxiety that no poison should be used in the area grazed over by their herds.

Considering only the areas accessible to the observer, it might be supposed that birds particularly interested in locusts would be absent from the immediate neighbourhood of Muhesa and noticeably abundant on the heavily infested river-bank at Kwa Lua and at Mavungwe. In order that the relation between the bird-population and the locusts may be appreciated in detail, a list of all the species of birds observed is given below, divided into the three categories into which the birds fall in their relation to the hoppers. As less than a week was spent in the area and but little collecting was done, the list must of course be regarded as only a very partial one of the local avifauna, and as somewhat unsatisfactory from the point of view of ornithological systematics. My acquaintance with the birds of this part of Africa in the field is, however, sufficient for me to present the list with confidence, and I believe that no numerically important species is omitted.

Category A.

Birds confined to the "mbuga" or the river bank, excluding the Kwa Lua reach, and therefore not naturally coming into direct contact with the hoppers.

<i>Anhinga rufa rufa</i> , Lacep. & Dand.	African Darter.
<i>Ardea goliath</i> , Cretzsch.	Goliath Heron.
<i>Mesophoxys intermedius brachyrhynchus</i> (Brehm)	African Yellow-billed Egret.
<i>Ardeola ralloides ralloides</i> (Scop.)	Squacco Heron.
<i>Ardeirallus sturmii</i> (Wagl.)	African Dwarf Bittern.
<i>Scopus umbretta bannermani</i> , C. Grant	Greater Hammerkop.
<i>Threskiornis aethiopicus aethiopicus</i> (Lath.)	Sacred Ibis.
<i>Hagedashia hagedash erlangeri</i> , Neum.	East African Hadada.
<i>Alopochen aegyptiacus</i> (Linn.)	Egyptian Goose.
<i>Cuculus vocifer</i> (Daud.)	African Sea-eagle.
<i>Coturnix</i> (sp. ?)	Quail.
<i>Limnocolaptes flavirostris</i> (Swains.)	Black Crake.
<i>Hoplopterus armatus</i> (Burch.)	Blacksmith Plover
<i>Burhinus</i> (sp. ?)	Stone-Curlew.
<i>Actophilus africanus</i> (Gmel.).	African Lily-trotter.
<i>Corythoides leucogaster</i> (Rüpp.)	White-bellied Goaway-bird.

These curious and noisy birds seemed to be strictly confined to the tall trees on the bank of the river.

<i>Ceryle rudis rudis</i> (Linn.)	Pied Kingfisher.
<i>Corythornis cristata cristata</i> (Pall.)	Malachite Kingfisher.
<i>Ispidina picta</i> (Bodd.)	Pygmy Kingfisher.
<i>Halcyon leucocephala</i> (subsp. ?)	Greyheaded Kingfisher.

Melittophagus pusillus (Mull.) (subsp.?)
Lybius torquatus irroratus (Cab.)

Little Bee-eater.
 East African Black-collared
 Barbet.

Dendropicos (? *lafresnayi hartlaubii*, Malb.)

Zanzibar Green-backed Cardinal
 Woodpecker.

Xanthophilus bojeri, Fischer

Golden Weaver.

Only seen in bushes growing on the south bank of the river and on islets. The north bank opposite them was alive with hoppers.

Hyphantornis jacksoni, Shelley

Jackson's Weaver.

Motacilla aguimp, Dumont

African Pied Wagtail.

It is noteworthy that no single individual of any of these species was seen out of its natural habitat or displaying any interest in locust-hoppers.

Category B.

Birds inhabiting the thorn-bush and therefore normally brought into contact with the hoppers, but not apparently paying any particular attention to them. I have put into this category, rather than the succeeding one, birds that appeared to occur equally commonly in locust-free and locust-infested areas.

Struthio camelus massaicus, Neum.

Masai Ostrich.

A few parties of about half a dozen in the thorn-scrub.

Pseudogyps africanus (Salvad.)

African White-necked Vulture.

Eupodotis canicollis canicollis (Reichw.)

White-bellied Knorhaan.

Lissotis melanogaster (Rüpp.)

Black-bellied Bustard.

A single bird with a brood of chicks in the densely infested area near Mavungwe.

Rhinoptilus africanus gracilis (Fisch. & Reichw.)

Masai Two-banded Courser.

Turtur afer kilimensis (Mearns)

Blue-spotted Wood-dove.

Centropus superciliosus, Hemp. & Ehr. (subsp.?)

White-browed Coucal.

Colius striatus, Gm. (subsp.?)

Speckled Mousebird.

Only at Hedaru.

Tricholaema melanocephalum stigmatothorax, Cab.

Brown-throated Barbet.

Trachyphonus darnaudii boehmi, Fisch. & Rchw.

Black-headed d'Arnaud's Barbet.

Bradornis griseus griseus, Rchw.

Grey Shrike Flycatcher.

Hirundo smithii smithii, Leach

Wire-tailed Swallow.

Bias musicus (Vieill.)

Crested Flycatcher.

Harpolestes minor, Rchw.

Lesser Scrub Shrike.

Dicrurus assimilis (Shp.)

Drongo.

Only single birds (at Hedaru) of both the last species.

Textor niger intermedius, Cab.

Buffalo Weaver.

Dinemellia (sp.?)

Giant Weaver.

N.B.—The six species of finch that follow were observed only at Hedaru.

Hyphantornis nigriceps nigriceps, Lay.

Black-headed Weaver.

Vidua serena, Linn.

Common Pied Whydah.

Hypochera (sp.?)

Indigo Finch.

Pytelia melba (Linn.) (subsp.?)

Fire-throated Finch.

Lagonosticta brunneiceps (Shp.) (subsp.?)

Crimson Finch.

Estrilda astrild (Linn.) (subsp.?)

Red-eyebrowed Grass Finch.

The last four species of finch were observed to be busily picking up split meal at Hedaru Station while the track a few yards away was swarming with very young locusts.

<i>Macronyx ameliae wintoni</i> , Sharpe	Red-throated Long-clawed Pipit.
<i>Zosterops</i> (sp.?)	White-eye.
<i>Anthreptes longuemarii</i> (Less.)	Purple White-bellied Sunbird.
<i>Cisticola</i> (sp.?)	Warbler.
<i>Prinia mystacea</i> , Rüpp. (subsp.?)	Wren Warbler.
<i>Erythropygia ruficauda</i> (subsp.?)	Red-tailed Scrub Chat.

Of these 29 species probably only one, the Swallow, is physically incapable of taking hoppers at any age ; though the last four of the finches are so tiny that they could only deal with very newly hatched insects.

Category C.

Birds in respect of which there is some sort of evidence that they were feeding on hoppers.

<i>Pternistes leucoscepus infuscatus</i> , Cab.	East African Bare-throated Francolin.
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Specimens shot had eaten hoppers. These birds were far more common close to Muhesa before that area was cleared of hoppers.

<i>Acryllium vulturinum</i> (Hardw.)	Vulturine Guinea-fowl.
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Small flocks were at first not uncommon. They disappeared from the immediate neighbourhood of Muhesa as it was cleared of locusts.

<i>Neotis cafra cafra</i> (Licht.)	Stanley's Bustard.
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Three small parties. A specimen obtained had been feeding on hoppers.

<i>Bucorvus cafer</i> (Schleg.)	Ground Hornbill.
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A party of 3 on the infested Kwa Lua bank.

<i>Lanius caudatus</i> , Cab.	Shrike.
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They occurred singly or in pairs round Muhesa in the thorn-bush in areas that had been cleared of hoppers ; but at Mavungwe several dozen were observed in flocks in a very heavily infested area.

<i>Laniarius nigerrimus</i> , Rchw.	Coast Black Shrike.
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A party of a dozen at Kwa Lua.

<i>Spreo superbus</i> , Rüpp.	White-banded Glossy Starling.
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Only a few small parties, except at Mavungwe, where about a hundred birds were concentrated into a small part of the hopper area together with *Lanius caudatus* and the Starling next mentioned.

<i>Perissornis carunculatus</i> , Gm.	Wattled Starling.
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Several flocks averaging about a hundred birds each, always in an infested area. This is the " Lesser Locust Bird " of South Africa.

Discussion and Conclusion.

It will be seen that of the 63 species noticed, there are only 8 in respect of which there are any grounds for supposing that they were paying particular attention to the locust-hoppers. These 8 are made up of a francolin, a guinea-fowl, a bustard, a ground hornbill, 2 shrikes, and 2 species of starling, all birds whose habit is either to concentrate on the grasshopper tribe or to take them greedily when they are offered. Of these 8 species, the first 4 taken together did not number more than 50 individuals ; the last 4 were more numerous, but only the wattled starlings, which are so to speak professional locust-hunters, were to be numbered in hundreds.

It is noteworthy that not a single one of the riverine birds (Category A) was seen to leave its ordinary avocations to take advantage of the ample food-supply provided by the hoppers on the very edge of the water (as at Kwa Lua) ; and powerful weavers such as *Textor*, able to deal with quite large hoppers, were observed to be foraging on the locust-free ground, although hoppers were abundant a mile away.

The list does not include a single species that might be expected to be a non-resident ; all are thoroughly typical of the country in which they were found. I observed no storks or cranes, although Dr. Worsley tells me that on one occasion a flight of some birds of this type made a brief appearance. It appears that the abundance of food in the area of country studied attracted no birds from other areas.

From the relative numbers of locust-hoppers and of birds preying upon them it is clear that in this particular instance the influence of the birds upon the plague must have been negligible. This is definitely at variance with observations made on the occasion of locust outbreaks in South Africa (see repeated references in the Reports of the South African Locust Bureau) and in Uganda (Capt. C. R. S. Pitman *in lit.*). It is possible that the number of locust-eating birds observed on the Pangani was so insignificant because the area was only on the fringe of an exceedingly widespread and severe infestation which began, and was centred, in Kenya. It is, on the other hand, possible that these Pangani conditions are typical of those that exist during locust outbreaks in Tanganyika, the Territory for some reason not being well served by birds of the right kind. Further observations are desirable.

NEW SPECIES AND HOST RECORDS OF ICHNEUMONIDAE AND BRACONIDAE.

By D. S. WILKINSON,
Senior Assistant, Imperial Bureau of Entomology.

ICHNEUMONIDAE.

Phaenolobus alcides, sp. n.

♀♂. Cadmium-yellow; vertex and occiput medianly, mesonotum posteriorly in the angle formed by the notauli, black (fig. 1); scape above and flagellum very dark

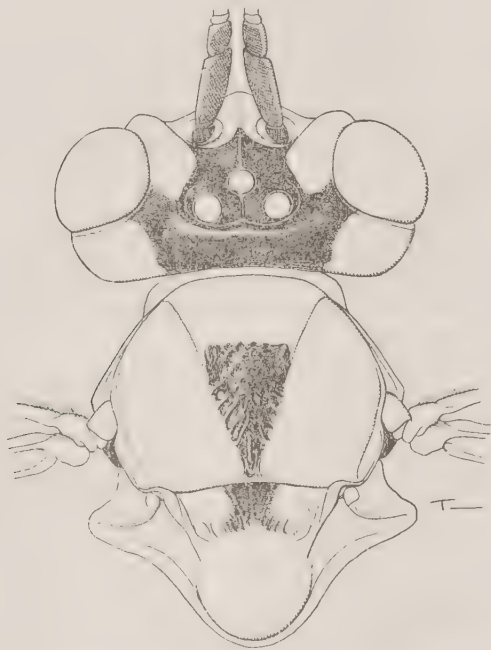


Fig. 1. *Phaenolobus alcides*, sp. n.: head, mesonotum, and scutellum, to show extent of the markings.

brown to black; hind tarsi very dark brown to black with flavescent pilosity; the apical tergites above commonly with a small dark mark; ovipositor red, the sheaths brown with flavescent pilosity; wings slightly and evenly infumated, except at apex, where they are decidedly darker, that is to say, in the forewing the apical half of the 3rd cubital and 2nd discoidal cells, and the apical fourth of the 2nd brachial cell, and in the hind wing the apical third of the radial, about the apical third of the cubital, and the extreme apex of the discoidal cells; the majority of the wing-veins dark red-brown, but black in the basal half of the forewing; in the forewing, the stigma, the costal vein (as opposed to the subcostal vein), and the medial at base, in the hindwing all veins at base of wing, and the majority of the anal vein in both wings, yellow testaceous, but often appearing rather darker owing to setae.

♂♂. *Head*: clypeus normally rugoso-punctate; face coarsely rugose; vertex and occiput smooth with some sparse punctation; facial depressions* conspicuous, just lower than the ocellar line, nearer to each other than to the eyes, nearer to the apex of the clypeus than to each other; flagellum with 23–26 joints, but more usually 24 or 25. *Thorax*: mesonotum with strong, separated punctation; notauli complete, converging posteriorly and virtually meeting, deeply impressed, narrow, and smooth save in the posterior third in the angle formed by their junction where the whole area is carinately rugose; scutellar sulcus broad and deep, weakly crenulate; disc of scutellum with punctures rather weaker than those of the mesonotum; mesopleurae with punctures rather stronger and more widely separated than those of the mesonotum, with an entirely smooth area posteriorly in the upper half; propodeon completely areated, with the median length of the petiolar area greater than the combined median lengths of the areola (*area superomedia*) and basal area; the petiolar area (whose anterior bounding carina is nearly completely semicircular) virtually entirely smooth, the remaining areae indefinitely rugulose. *Legs*: claws of the four anterior legs unidentate beneath, of the hind legs simple. *Abdomen* at the most with minute (degree 1) and sparse punctures, otherwise smooth; 1st tergite with apical breadth normally rather more than twice, and with basal breadth about one-fourth, the median length, with its sides straight, its apical angles not rounded, and its apex bisinuate on account of a smooth median protuberance; hypopygium large, pointed; ovipositor and sheaths elongate, but shorter than the abdomen.

Length, 8.0–10.0 mm.

TANGANYIKA TERRITORY: Morogoro, 8 ♀♀ (one the *type*), 6 ♂♂, 1 ?, vii.1922 (*A. H. Ritchie*). UGANDA: Mpanga Forest, Toro, 4,800 ft., 1 ♀, 13–23.xi.1911 (*S. A. Neave*); Kafu River near Hoima, Kampala Road, 3,500 ft., 1 ♀, 29–31.xii.1911 (*S. A. Neave*); shores of Lake Isolt or Wamala, 3,800 ft., 1 ♀, 7–8.i.1912 (*S. A. Neave*).

Type deposited in the British Museum.

Host. Mr. Ritchie's series was bred from the weevil, *Alcides erythropterus*, Chev., which makes galls on *Dolichos* sp.

I am indebted to Dr. Roman, of Naturhistoriska Riksmuseet, Stockholm, for the correct placing of this interesting species. In his letter to me, Dr. Roman states definitely that this is neither one of Tosquinet's species (under *Acoenites*), nor one of Holmgren's, nor *P. flavus*, Roman (= *luteus*, Szép.). *P. major*, Szép. 1914, is unrecognisable from the description, and I am not aware of any other described species from Africa.

Melanichneumon muciallae, sp. n.

♀. Black with the following parts yellow: face (except medianly), clypeus laterally, frontal orbits broadly to the level of the anterior ocellus, cheeks, lower posterior orbits and occiput very broadly, scape below, basal two or three joints of flagellum to some extent, the pronotum narrowly right across the anterior margin, the pronotum broadly along the posterior upper margins as a line on each side reaching to the tegulae but not quite joining in front, a fold of the mesopleurae immediately under the tegulae, the scutellum, the tegulae, the metanotum immediately behind the scutellum, the dentiparal and postero-intermedial areae of the propodeon wholly, the petiolar area at base, the spiracular area in apical half, the areola at apex, the fore and middle coxae to a large extent, the hind coxae above and apically, fore and middle femora at apex, the fore tibiae, the whole apex of the petiole posterior to the spiracles,

* In previous papers I have in a number of instances inadvertently used the term *toruli* when referring to the facial depressions (invaginations leading to the tentorial apodemes). In one or two instances, however, this term has been correctly applied by me, namely, in referring to the antennal sockets, but the context should be sufficient to indicate where the errors have occurred.

the apical third of the 2nd and 3rd tergites ; legs otherwise (except the femora and coxae) to a large extent reddened ; flagellum, stigma, and wing veins, dark brown with some red.

♂. Agrees with the description of the colour of the ♀, but has additional yellow markings as follows : face and clypeus wholly (except for a small median area at apex of latter, and the cheeks narrowly), a large median area of the mesopleurae, the spiracular areae of the propodeon wholly, the greater part of the four anterior legs (except their femora behind), the apical two-fifths to one-half of the 2nd, 3rd, and 4th tergites, and the apical fourth of the 5th tergite.

♀. *Head* weakly and sparsely punctate ; both face and clypeus short, strongly transverse ; flagellum short and stout, with 25-26 joints. *Thorax* : mesonotum and scutellum regularly, but not strongly, punctate ; propodeon strongly but sparsely punctate, with the petiolar area strongly excavated. *Legs* : femora short and stout ; the hind coxae below dentate. *Abdomen* : postpetiole sparsely and fairly strongly punctate, the interstices highly polished ; 2nd and 3rd tergites strongly and closely punctate, the succeeding tergites with only minute, but fairly close, punctuation.

♂. *Head* : face closely and fairly strongly punctate ; frons and vertex regularly and more strongly punctate than in the ♀ ; both face and clypeus transverse, but not strongly so, both distinctly longer than in the ♀ ; flagellum setaceous, with 27 joints. *Thorax* : mesonotum regularly and strongly punctate, but not so strongly as on the propodeon ; petiolar area strongly excavated. *Legs* : femora short and stout ; hind coxae below not dentate. *Abdomen* : postpetiole sparsely and fairly strongly punctate, the interstices highly polished ; 2nd tergite very strongly and closely punctate, almost rugoso-punctate ; 3rd and 4th tergites strongly and closely punctate, the succeeding tergites with only minute, but fairly close, punctuation.

Length, 8-10 mm.

JAVA : Banjoewangi, 3 ♀♀, 4 ♂♂, x.1929 (R. W. Paine).

Type deposited in the British Museum.

Host. Bred from pupae of an unidentified species of the Pyralid genus, *Tirathaba*.

Dr. Roman was good enough to examine this species for me, and in his reply he draws attention to the fact that it has two rare characters, namely, the dentation on the underside of the female hind coxae, and the lack of a white ring on the female antennae, remarking that the former, so far as he was aware, was unique in the genus. He states, finally, that this new species comes near, in coloration, to *Ichneumon ocellus*, from East Java, but is certainly different.

Nemeritis palmaris, Wilkinson (1928).

The Bureau has received from Mr. R. W. Paine from Banjoewangi, East Java, 3 ♀♀, x.1929, bred by him from larval stages of a Pyralid, *Tirathaba* sp. This parasite was originally described from Malaya, from *Tirathaba rufivena*, Walk.

BRACONIDAE.

Rhaconotus sudanensis, Wilkinson (1927).

The Bureau has received from the Wellcome Tropical Research Laboratories, Khartoum, Sudan, 3 ♀♀, 2 ♂♂, bred from the same host as the type series, namely, *Sphenoptera gossypii*, Cotes. The males of this parasite were not previously known.

***Apanteles graciosus*, sp. n.**

♀♂. Differs notably from *A. pallidocinctus*, Gah., apparently only in the following characters: Tegulae considerably yellower than in *pallidocinctus*; disc of 2nd tergite invariably darkened; 1st tergite rather smaller and rather more attenuated, with some slight sculpturing at apex; hypopygium (fig. 2) large and acutely produced, ovipositor sheaths (fig. 2) elongate and narrow.

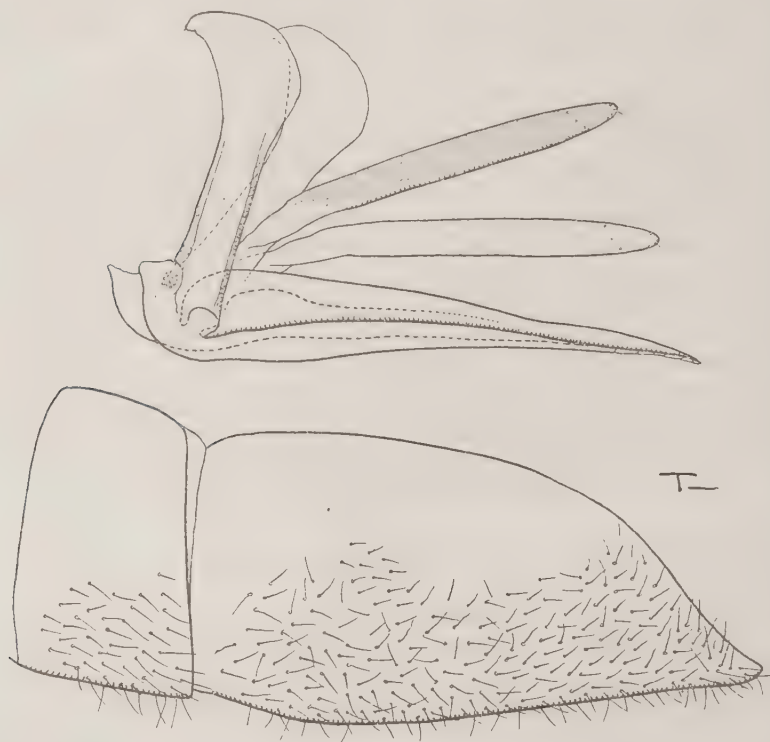


Fig. 2. *Apanteles graciosus*, sp. n.: external ♀ genitalia, and hypopygium.

Length, 3 mm.

UGANDA: Kampala, 30 ♀♀ (one the *type*), 16 ♂♂, 10.vi.1917 (C. C. Gowdey), 8 ♀♀, 1 ♂, 14.vii.1917 (C. C. Gowdey), and 5 ♀♀, 19 ♂♂, 8.vii.1927 (H. Hargreaves).

Type deposited in the British Museum.

Host unknown. Mr. Hargreaves' series was bred from a caterpillar on a "Kokowe" leaf; Mr. Gowdey's June series bears the number 5845, and the July series, 6148.

Cocoons red-brown, as in *pallidocinctus*.

This species is very close to *pallidocinctus* but differs considerably in the form of the female external genitalia. The genitalia of both *pallidocinctus* (fig. 3, c & d) and *papilionis* (fig. 3, a & b), this latter species being also closely related, have been figured for comparison.

It will be extremely interesting if the host of this new species is shown subsequently to be the larva of a Papilionid butterfly; it should be remarked that, so far as can

be remembered, on each of the three occasions when this species was forwarded to the Bureau for identification, there were forwarded at the same time specimens of *pallidocinctus*.

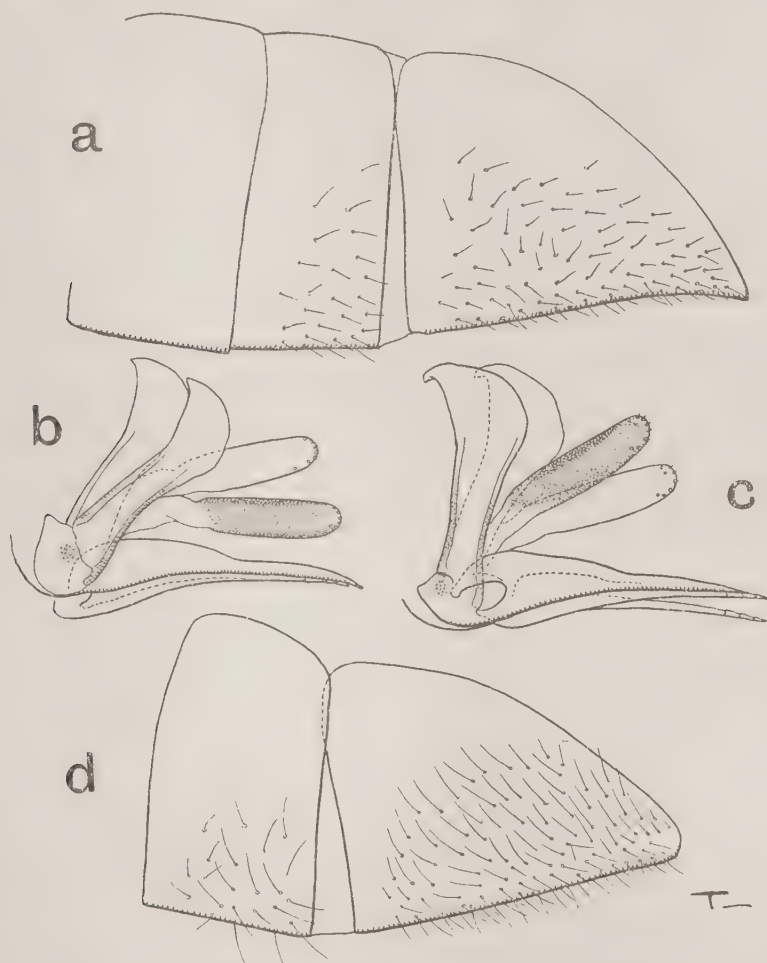


Fig. 3. Hypopygium and apical ventrites, and the external ♀ genitalia of: *a, b, Apanteles papilionis*, Vier.; *c, d, A. pallidocinctus*, Gah.

***Apanteles flavipes*, Cameron (1891).**

The Bureau has received from Mr. H. T. Pagden from Titi Serong, Malaya, the following series of this species: 17 ♀♀, 7 ♂♂, 18.iv.1929, parasitic on larvae of *Diatraea* sp. in padi; 16 ♀♀, 1 ♂, 7.vii.1929, parasitic on *Diatraea* sp. in maize; and 14 ♀♀, 30.vi.1929, bred from ova of *Diatraea auricilia*, Dugd.

***Apanteles chinensis*, sp. n.**

♀♂ Black; tegulae, legs (including all coxae), and to a large extent the ventrite and hypopygium, red testaceous; palpi and tibial spurs pale; antennae red-brown

the scape red-brown or red testaceous; wing veins pale, the costal vein more or less testaceous, and the stigma and metacarp brown.

♀♂. *Head* minutely punctate (degree 1); face with clypeus differentiated, and the facial depressions definitely nearer to apex of clypeus than to eyes. *Thorax*: mesonotum shining and smooth, with minute, rather close, punctation; scutellar sulcus straight, with more than eight major carinae; disc of scutellum like the mesonotum, but with less punctation; propodeon dull, roughened to rugose, a faint median longitudinal carina sometimes just apparent, and transverse basal carinae more usually fairly well marked but sometimes obscure. *Wings*: the 1st abscissa of the radial in length less than the breadth of the stigma, longer than and definitely angled with the transverse cubital, which latter is equal to the recurrent; apical portion of 1st abscissa of cubital shorter than recurrent, longer than upper portion of basal vein, barely longer than the pigmented portion of the 2nd abscissa of the cubital; stigma in length about equal to metacarp. *Legs*: hind coxae on outer faces polished and shining, with some minute punctation only, basally above with a group of fairly strong, more or less indefinite, punctures; hind tibial spurs equal, half the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite in basal half excavate, smooth (except possibly laterally), in apical third or half turned over and down and with coarse (degree 3-4) punctures that give almost a rugose appearance, the tergite in shape very much like that of *taprobanae*, Cam., but with the apical angles more rounded; 2nd tergite indefinitely roughened, with the lateral sulci barely more than indicated, in shape also much like that of *taprobanae*; 2nd suture fairly well marked; 3rd and succeeding tergites smooth save for the usual sparse minute punctures; hypopygium (fig. 4) viewed from side slightly excavate immediately above apex; ovipositor sheaths short.

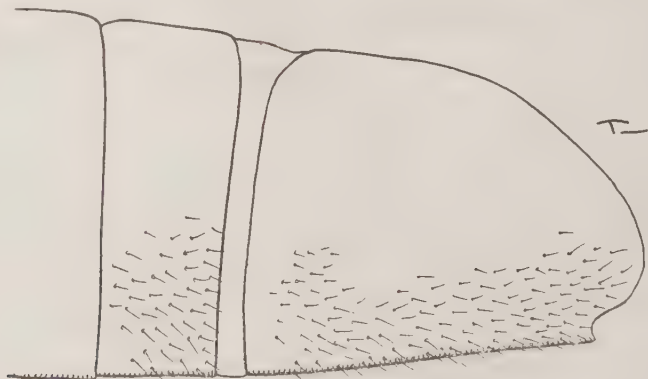


Fig. 4. *Apanteles chinensis*, sp. n.: hypopygium and apical ventrites.

Length, 2.5 mm.

CHINA: Foochow, 43 ♀♀, 8 ♂♂, 1928 (C. R. Kellogg).

Type deposited in the British Museum.

Host unknown: the series is labelled "713, parasitic on larva of a Nymphalid, ? *Athyma*."

Cocoons unknown.

This species is immediately separable from its allies by the nature of the punctation on the mesonotum. Following the description of the next species I have given a key to those species of this group that are known to me that possess red testaceous hind coxae.

***Apanteles flagellator*, sp. n.**

♀♂. Black; tegulae, all legs (except as follows), the majority of the basal ventrites, the lateral membranous margins of the basal tergites, the lateral thirds of the apical tergites of the females, red testaceous; the extreme apex of the hind femora, the apex of the hind tibiae, the hind tarsi, very slightly darkened; scape red, red-brown, to nigrescent, the flagellum red-brown; mouth-parts reddened and the palpi pale; hind tibial spurs pale; stigma and wing veins pale red-brown.

♀♂. *Head* with only minute punctures; facial depressions somewhat nearer to apex of clypeus than to eyes; posterior ocelli nearer to each other than to eyes. *Thorax*: mesonotum coarsely punctate, the punctures not always clearly differentiated; the scutellar sulcus broad, with four or five (very rarely six) major carinae; propodeon rugose or broadly reticulate, with transverse basal and median longitudinal carinae. *Wings*: the length of the transverse cubital equal to the breadth of the stigma, longer than the recurrent, this latter again longer than the 1st abscissa of the radial; the apical portion of the 1st abscissa of the cubital about equal to the pigmented portion of the 2nd abscissa, about half the length of the transverse cubital, rather shorter than the 1st abscissa of the radial; stigma shorter than metacarp. *Legs*: hind coxae with some indefinite coarse punctures basally above, in the greater part smooth and shining save for minute punctation; hind tibial spurs subequal, the shorter spur half the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite entirely smooth in the excavate basal half, very definitely sculptured (weakly rugose) in the apical half (which is turned over), with the median length nearly twice the basal breadth (18:10), virtually parallel-sided or somewhat narrowed in basal half, then gradually widening in the apical half, with the greatest width shortly before the rounded and slightly emarginate apex, this latter rather narrower than the basal breadth and definitely narrower than the greatest breadth (8:10:12); 2nd tergite weakly rugose laterally, with the apical breadth of the disc nearly twice its basal breadth, about 2.25 times its median length, and equal to the median length of the 1st tergite (18:10:8:18), with the rounded discal sulci and the 2nd suture well marked, the latter evenly curved; 3rd tergite smooth save for the usual minute puncturing, considerably longer than the 2nd tergite (12:8); ovipositor sheaths short, the hypopygium more or less truncated.

Length, 2 mm.

UGANDA: Kampala, 15 ♀♀, 4 ♂♂, 2.ix.1917 (C. C. Gowdey).

Type deposited in the British Museum.

Host unknown; the specimens bear the number 6252.

Cocoons unknown.

This species is very close to *americanus*, Lep., but may be easily separated on a variety of small but definite characters. For example, in *americanus* the 1st abscissa of the radial is longer than the transverse cubital, the 2nd suture is not evenly curved, but bisinuate, and the 3rd tergite is only somewhat longer than the 2nd (12:10). The most satisfactory characters, however, are those that I am using in my revised key, and the relevant portion of this key, as at present constituted, namely, that portion dealing with species of this group having red testaceous hind coxae, is given below:—

- | | | |
|----|---|-----------------------------|
| A. | Mesonotum, at least in posterior half, with only minute punctation (degree 1 or at most 2) | <i>chinensis</i> , sp. n. |
| | Mesonotum strongly punctate (at least degree 2-3) | B. |
| B. | Scape for the greater part red testaceous; scutellar sulcus with at least eight carinae | C. |
| | Scape dark red to nigrescent; scutellar sulcus with at most five carinae | <i>flagellator</i> , sp. n. |

- C. Posterior ocelli nearer to eyes than to each other; scutellar sulcus slightly but definitely curved; propodeon with normally strongly marked transverse basal carinae *rufiventris*, Bingh.

Posterior ocelli not nearer to eyes than to each other; scutellar sulcus straight; propodeon with transverse basal carinae normally very weakly marked
americanus, Lep.

***Apanteles annulicornis*, Ashm.**

Pseudapanteles annulicornis, Ashmead, Trans. Ent. Soc. London, 1900, p. 292.

Pseudapanteles brunneus, Ashmead, Trans. Ent. Soc. London, 1900, p. 292 (syn. nov.).

Apanteles annulicornis, Ashmead, Muesebeck, Proc. U.S. Nat. Mus., lviii, 1920, p. 525; Wilkinson, Bull. Ent. Res., xix, 1928, p. 109.

Apanteles brunneus, Ashmead, Muesebeck, Proc. U.S. Nat. Mus., lviii, 1920, p. 525.

Ashmead in his description of *brunneus* was in error in describing the scutellum, the metathorax, the hind coxae, and the 1st tergite as black, these parts, and others, in fact being only rather dark red testaceous, owing possibly to indifferent condition or perhaps to the circumstance that this particular specimen is undersized. He was in error also in using the term honey-yellow, and thus wrongly emphasising the colour differences in the two descriptions: the species is correctly describable as red testaceous.

Since Ashmead's description under the name *brunneus* is indifferent, and the unique male somewhat abnormal, and since the name *annulicornis* is so extremely suitable, I have adopted this latter name despite the page priority of the former, a priority that, in these particular circumstances, is entirely negligible.

***Apanteles rufulus*, sp. n.**

♀. Black; scape (except at apex), tegulae, the four anterior legs (except the middle coxae), hind trochanters and trochantines, hind femora, 3rd and succeeding tergites, the lateral membranous margins of the basal tergites, all the ventrites and pleurites (including the hypopygium and ovipositor, but not the sheaths of the ovipositor), red testaceous; apical half of hind tibiae, the hind tarsi, flagellum, and stigma, brown, the latter with a cloud basally; remaining wing veins red-brown to red testaceous; mouth-parts, basal half of hind tibiae, hind tibial spurs, and the metatarsus basally, pale; the apical tergites somewhat darkened at apex.

♀. *Head*: the posterior ocelli about equidistant from each other and from the eyes. *Thorax*: mesonotum with close, minute punctation (degree 2); disc of scutellum level with the mesonotum, with some extremely minute punctures (degree 1), largely impunctate, polished and shining, evenly rounded with the lateral faces; the scutellar sulcus almost straight, slightly curved laterally, its crenulations small; propodeon in basal two-thirds regularly and closely punctate (degree 3), apically with some smooth, shining areas, the areola indicated only apically and by more or less indefinite carinae. *Wings*: the 1st abscissa of the radial shorter than the breadth of the stigma, longer than the recurrent, one and a half times as long as the transverse cubital, this latter twice as long as the pigmented portion of the 2nd abscissa of the cubital, which is equal to the upper portion of the basal vein; the apical portion of the 1st abscissa of the cubital just shorter than the recurrent, just longer than the transverse cubital; stigma shorter than metacarp. *Legs*: hind coxae basally above with close punctation (degree 2-3); the longer hind tibial spur just less than half, and the shorter spur two-fifths, the length of the basal joint of the hind tarsus. *Abdomen*: the 1st tergite much like that of *A. hyblacae*, Wilkn., in general shape except that it is relatively rather narrower, with the apical breadth about three-fourths the median length, and the basal breadth just a little narrower,

with the sides straight or just somewhat bisinuate, the apical angles acute, the apex slightly arcuately emarginate, and with the integument in basal half finely aciculate, and in apical half striato-punctate (the punctures (degree 3) almost obscured), and with a small smooth area at middle at apex, the tergite strongly turned over and down, medianly weakly tumescent, and basally in the middle weakly excavate; 2nd tergite in shape much like that of *A. trochanteratus*, Szép., basally as broad as, and conforming with the shape of, the apex of the 1st tergite, apically strongly and evenly rounded, with the apical breadth rather shorter than the median length of the 1st tergite, and about 3.25 times its own median length, with the lateral sulci rounded and, like the 2nd suture, well marked, with the integument much like that of the apical half of the 1st tergite, only rather more weakly marked; 3rd and succeeding tergites smooth; hypopygium acute, produced; ovipositor sheaths apparently rather longer than the hind tarsus.

Length, 3 mm.

INDIA: 1 ♀, undated.

Type deposited in the British Museum.

Host. This unique specimen is labelled as having been bred from Kusum lac.

Cocoons unknown.

This species, which was described at the special request of the late Dr. James Waterston, runs in my revised key to *trochanteratus*, Szép., and *hyblaeae*, Wilkn., from which it may be separated as follows:—

Mesonotum with strong, well-separated punctures (degree 3-4); propodeon almost entirely strongly rugoso-reticulate; 1st and 2nd tergites rugose; 2nd tergite at apex strongly curved *trochanteratus*, Szép.

Mesonotum with definite, more or less separated, shallow punctation; propodeon only indefinitely punctate, largely smooth; 1st and 2nd tergites largely smooth; 2nd tergite at apex straight *hyblaeae*, Wilkn.

Mesonotum with close, minute punctation (degree 2); propodeon closely punctate (degree 3) in basal two-thirds; 1st and 2nd tergites striato-punctate; 2nd tergite at apex strongly curved *rufulus*, sp. n.

***Apanteles diatraeae*, Muesebeck (1920).**

We have received from Dr. J. G. Myers, in Trinidad, 2 ♀♀, 1 ♂, 23.ii.1929, reared by him from *Diatraea* sp. in maize. He states that this is the chief, if not the only, parasite of the maize *Diatraea*, and further that he has not once reared it from *Diatraea* in sugar-cane.

***Apanteles tirathabae*, Wilkinson (1928).**

The Bureau has received from Mr. R. W. Paine from Buitenzorg, Java, 10 ♀♀, 10 ♂♂, viii.1929, and 8 ♀♀, 2 ♂♂, ix.1929, bred by him from *Tirathaba* sp. This is the first authentic host record, as previously this species was only believed to be parasitic on *Tirathaba*. Mr. Paine says that this *Apanteles* alone causes as much as 20 per cent. parasitism.

The cocoons of this species have now also been received: they are white.

***Microgaster vacillatrix*, sp. n.**

♀. Black; mouth-parts, scape largely, tegulae, all legs (except hind tarsi and about apical half of hind tibiae), all ventrites including hypopygium and ovipositor, the two basal tergites with their lateral membranous margins, red testaceous; hind

tibial spurs pale ; ovipositor sheaths black ; flagellum, stigma and wing veins brown ; wings slightly and evenly infumated throughout.

The mesonotum, particularly in the middle posteriorly, the propodeon, and other parts of the thorax, commonly strongly reddened, but the mesonotum never completely red.

♂. Black ; scape to some extent, tegulae, the four anterior legs, the hind trochanters and hind femora and the basal half of the hind tibiae, the 1st tergite with its lateral membranous margins, and the basal ventrites, red testaceous ; hind tibial spurs pale ; stigma and wing veins brown ; wings slightly and evenly infumated throughout.

♀♂. *Head* : face and clypeus with minute punctation ; vertex and frons almost smooth ; posterior ocelli nearer to each other than to the eyes, their distance from the eyes very considerably greater than the diameter of an ocellus ; antennae of ♀ about equal to combined lengths of head, thorax and abdomen, those of the ♂ very definitely longer. *Thorax* : mesonotum punctate (degree 3), the punctation decidedly weaker posteriorly (degree 1) ; disc of scutellum with some minute punctures ; propodeon smooth and shining, save for a well-marked, median, longitudinal carina. *Wings* : the recurrent equal in length to the 2nd abscissa of the cubital, rather shorter than the 1st transverse cubital, longer than the apical portion of the 1st abscissa of the cubital, this latter half the length of the 1st abscissa of the radial, which is equal to or possibly rather shorter than the breadth of the stigma, and which is 1.5 times as long as the recurrent ; the hyaline 2nd transverse cubital about equal to the upper portion of the basal vein, about half the length of the recurrent ; the 2nd abscissa of the radial apparently entirely wanting, the 2nd transverse cubital received into the 1st radial at the junction of this vein with the 1st transverse cubital, thus making the areolet large and triangular ; stigma shorter than metacarp. *Legs* : hind coxae in upper half smooth and shining, and with only sparse, minute, or indefinite punctation ; the longer hind tibial spur about three-fifths, and the shorter spur one-third, the length of the basal joint of the hind tarsus. *Abdomen* : 1st tergite smooth and shining, excavate in the basal two-thirds, with weak indefinite sculpturing in apical third, with the median length twice the basal breadth, parallel-sided in the basal two-thirds, then narrowing to the truncated apex, the breadth of which is one-third the median length ; 2nd tergite with median length one-fourth apical breadth and decidedly less than basal breadth, with its lateral sulci consequently widely divergent, and, like the 2nd suture, weakly crenulate (except in the ♂ where they are virtually smooth), the tergite otherwise smooth ; 3rd tergite entirely smooth (save for some minute punctures), as are the succeeding tergites, with its median length in the ♀ twice that of the 2nd tergite, and in the ♂ rather less than twice ; hypopygium large, acute ; ovipositor sheaths about equal in length to hind femora, without process.

Length : ♀, 2.5-3.0 mm. ; ♂, 2.3 mm.

UGANDA : Kampala, 10 ♀♀, 2 ♂♂, 17.ix.1929 (*H. Hargreaves*).

Type deposited in the British Museum.

Host unknown ; the specimens are labelled " A 171, ex larva of ? 7167."

Cocoons white.

If the mesonotum is taken to be black, *M. vacillatrix*, in my key for the Indo-Australian and Ethiopian species of *Microgaster* (Trans. Ent. Soc. London, 1929, p. 99), runs to *M. psaræ*, Wilkn. (India and Malaya), and in many respects is much like this species, differing markedly, however, in the sculpture of the face and in venational characters. Taking the mesonotum to be red, the species would run to *M. bicolor*, Szé. (Tanganyika Territ.), or *M. indica*, Wilkn. (India), from both of which it is immediately separable on the length of the ovipositor sheaths.

Microgaster imitator, Ashm.

Urogaster imitator, Ashmead, Trans. Ent. Soc. London, 1900, p. 288.

Apanteles imitator, Ashmead, Szépligeti, in Wytsman Gen. Ins., fasc. 22^b, 1904, p. 110; Muesebeck, Proc. U.S. Nat. Mus., lviii, no. 2349, 1920, p. 504.

The 2nd transverse cubital is hyaline and minute, but definitely present, the hind coxae are large, and the longer hind tibial spur is rather longer than half the basal joint of the hind tarsus. The species is represented, I believe, by the unique specimen in the British Museum, and this had not been seen by Muesebeck at the time he wrote his revision of the North American species of *Apanteles*. The head of the specimen is missing.

Microgaster psarae, Wilkinson (1927).

The Bureau has received from Dr. J. C. Hutson from Ceylon 1 ♀, 2 ♂♂, bred from the larva of a Pyralid leaf-roller on *Solanum melongena*. This is the first record of this species in Ceylon.

Meteorus dichomeridis, sp. n.

♀♂. Red to red testaceous; apical half of 1st tergite darkened to black; stigma discally hyaline or virtually so; the reticulate carinae of the propodeon often somewhat darkened.

♀♂. Head transverse; face minutely punctate and aciculate, in the female with minimum breadth hardly greater than the breadth of the clypeus, in the male rather broader; the posterior ocelli about equidistant from each other and the eyes, their distance from the eyes rather greater than the diameter of one ocellus; the ocellar region tumescent; flagellum with ? 24-26 joints (the majority of the specimens have their antennae broken), the antennae as long as or longer than the combined length of head, thorax, and abdomen. *Thorax*: mesonotum anteriorly and the parapsides only minutely punctate; the notauli present as fairly wide, shallow, roughened lines converging on a broad, slightly sunken, roughened, median area; propodeon coarsely reticulate, posteriorly concave in the middle. *Wings*: the 1st and 2nd abscissae of the radial about equal, shorter than the 2nd transverse cubital; the recurrent just, but distinctly, into the 1st cubital cell. *Abdomen*: the 1st tergite with median length twice apical breadth, with well marked, longitudinal striations in apical half, more or less smooth in basal half; remaining tergites more or less entirely smooth and shining; ovipositor sheaths rather shorter than the abdomen.

Length, 4 mm.

INDIA: Khanewal and Chichawatni Plantations, Punjab, 5 ♀♀, 5 ♂♂, 13-29.iv.1928, 8.viii.1928 (R. N. Mathur).

Type deposited in the British Museum.

Host. Recorded by the Forest Research Institute, Dehra Dun, to have been bred from larvae of the Gelechiid moth, *Dichomeris evidantis*, Meyr.

Cocoons very pale testaceous, with a fair amount of white silk.

Meteorus tabidia, sp. n.

♀♂. Black; head (except for a patch of black on the back which commonly extends into the ocellar region), scape, prothorax (except the pronotum above), about the lower half of the meso- and metathorax and of the propodeon, the tegulae, scutellum, the whole of all the legs, the 2nd tergite, the ventrites largely, the apical tergites to some extent (occasionally wholly and occasionally not at all), red to red testaceous; stigma and wing veins red-brown, the former somewhat paler at base; flagellum and ovipositor sheaths reddened.

♀♂. Head transverse; face with only minute sculpturing, virtually smooth, in the female with the minimum breadth hardly greater than the breadth of the clypeus,

in the male broader; posterior ocelli rather nearer to each other than to the eyes, their distance from the eyes definitely greater than twice the diameter of an ocellus; the ocellar region not or hardly tumescent; flagellum of female with 27-29 joints, the vast majority with 28 joints, of male with 29-30 joints, the antennae as long as or longer than the combined length of head, thorax, and abdomen. *Thorax* with the mesonotum anteriorly, and the parapsides, only minutely punctate; the notauli well marked, well impressed, roughened, converging on a broad, slightly sunken, rugose, median area; propodeon strongly and closely wrinkled-reticulate, posteriorly concave in the middle. *Wings*: the 2nd abscissa of the radial considerably longer than the 1st abscissa, shorter than the 2nd transverse cubital; the recurrent interstitial or just into the 2nd cubital cell. *Abdomen*: 1st tergite with median length about 2.5 times apical breadth, with well-marked, longitudinal striations in apical half, more or less smooth in basal half; remaining tergites more or less entirely smooth and shining; ovipositor sheaths about as long as the abdomen.

Length, 3.5-4.0 mm.

CEYLON: Rambakkana, 9 ♀♀ (one the type), 1 ♂, 13. viii. 1928 (Dr. J. C. Hutson); Peradeniya, 10 ♀♀, 4 ♂♂, 28.xii. 1920 (Dr. J. C. Hutson), 1 ♀, 9.x. 1914, 3 ♀♀, 2.xi. 1914, 1 ♀, 13.xi. 1914 (A. Rutherford).

Type deposited in the British Museum.

Host. Dr. Hutson's series was bred from larvae of the Pyralid moth, *Tabidia aculealis*, Walk., attacking sweet potato. Mr. Rutherford's specimen, dated 9th October, is also labelled "probably ex Lepidoptera feeding on *Argyrea populifolia*."

Cocoons red testaceous, sparsely supplied with silk of the same colour.

***Meteorus trichogrammae*, sp. n.**

♀♂. Red to red testaceous; apical half of 1st tergite black; the apical tergites, the ovipositor sheaths, and the reticulate carinae of the propodeon, often darkened; stigma and wing veins red-brown.

♀♂. *Head* transverse; face with some minute punctation, virtually smooth, in the female with the minimum breadth definitely less than the breadth of the clypeus, in the male broader; the posterior ocelli nearer to the eyes than to each other, their distance from the eyes equal to or hardly greater than the diameter of one ocellus; the ocellar region not or hardly tumescent; flagellum of female with 22-24 joints, more often 23, of male 24-26, the antennae of the female shorter than, and of the male about equal to, the combined length of head, thorax, and abdomen. *Thorax* with the parapsides punctate; the notauli present as fairly wide, shallow, roughened lines converging on a broad, slightly sunken, weakly rugose area, the mesonotum anteriorly being roughened; propodeon strongly and closely wrinkled-reticulate, posteriorly concave in the middle. *Wings*: the 1st and 2nd abscissae of the radial equal, shorter than the 2nd transverse cubital; the recurrent interstitial. *Abdomen*: 1st tergite with median length about twice to 2.5 times apical breadth, with well-marked, longitudinal striations in apical half, more or less smooth in basal half, and with a small conspicuous, deeply impressed pit on each extreme lateral margin of the tergite at the apex of the petiolar half slightly before the spiracles; remaining tergites more or less entirely smooth and shining; ovipositor sheaths about as long as the abdomen.

Length, 4 mm.

Fiji Is.: 6 ♀♀, 4 ♂♂, 1929 (T. H. C. Taylor).

Type deposited in the British Museum.

Host. Bred from larvae of the Pyralid moth, *Tirathaba trichogramma*, Meyr.

HALTICINAE (COL.) AS POSSIBLE FACTORS IN NATURAL CONTROL OF MOSQUITOS IN QUEENSLAND.

By R. HAMLYN-HARRIS, D.Sc.,
*City Entomologist, Brisbane.**

During a recent dry spell in the Brisbane area the canal situated at Nundah, known as Schultz's, had become silted, and various aquatic and other weeds had taken possession of the bed. Owing to pollution from a sewer, produced higher up, *Culex fatigans*, as is usual on such occasions, was breeding amongst the aquatic vegetation consisting mainly of *Eichhornia speciosa* (Water Hyacinth), *Hydrilla verticillata* (Water Thyme) and *Jussiaea repens* (Yellow Primrose). The large quantities of Characeae, usually so abundant in this canal during wet times, had completely disappeared.

During the dry weather, in spite of regular oilings, *Culex fatigans* continued to increase its sphere of activities, until nearly every part of the canal in the locality of the sewer was being selected.

During oiling operations it was noticed that wherever *Jussiaea repens* occurred in large quantities, a small insect seemed to be responsible for large black patches of dead vegetation, which when examined proved to be due to the depredations of the larvae and adults of a small Halticine beetle (7mm. long), viz., *Haltica ignea*, Blackb. The larvae, particularly, were present in thousands, small jet black grubs (11 mm. in length) actively engaged swimming in and out of the water, crawling about the stems and leaves and eating every available bit of green, the plant gradually turning black. But the interesting part about these black patches was that the water suffered discolouration also, and wherever mosquito larvae had existed before, they were now dead, whilst outside the black-patch area mosquito larvae disported themselves as usual.

Thus far my observations had gone when the drought broke suddenly and within 24 hours the rising waters had completely obliterated the scene of their activities.

That the poisonous properties of this beetle were not confined to the larvae is shown by the effects of the excreta of the adult upon the mosquito larvae present before ever the Halticine larvae came into existence, and I can only surmise that possibly most, if not all, stages of development would prove equally destructive.

Further investigations are of course necessary. I had intended to continue minute studies of the water and the possible factors involved, but the breaking of the drought prevented this.

As some time may now elapse before another such favourable opportunity may present itself, I publish this instance of direct biological control, in case other investigators may have an opportunity of making further and more detailed observations on the subject.

* From the Entomological Section, Dept. of Health, Brisbane City Council.

ON A COLLECTION OF LAC INSECTS FROM NORTHERN INDIA.

By AWADH BEHARI MISRA, D.Sc.

(From the Department of Zoology, Lucknow University, India.)

Introduction.

The lac insects have, in recent years, been the object of extensive attention, partly on account of their economic importance, and partly on account of the biological interest that invests them. What the late Professor Lefroy had remarked about the Aphids in his "Indian Insect Life" may well have been said of these also but for the appearance of Chamberlin's Monograph (Bull. Ent. Res., xiv, 1923, pp. 147-122; xvi, 1925, pp. 31-42), which supplied a long-needed treatise on the subject. The weakness of this monograph, however, has seemed to me to be the insufficient treatment of the Indian forms, which was, evidently, due to lack of material, and it has therefore seemed desirable to undertake a study of the Indian lac insects in order to fill in the lacunae in this otherwise excellent monograph.

Most of the material upon which this paper is based was collected by me during the summer of 1925, but a part of it was received from friends and co-operators, mention of whom has been made in the text.

Finally, I desire to thank Dr. G. S. Thaper, Ph.D., for certain kind assistance that I have received at his hands.

Previous Records of Lac Insects from India.

Out of a total of forty-three valid species of lac insects hitherto recorded, only nine have been reported from India, Burma and Ceylon. Of these, three are from Ceylon, so that only six species belong to India proper, namely, *Laccifer fici*, *L. ebrachiata*, *L. lacca*, *L. rangoonensis*, *L. theae*, and *Tachardina ternata*.

Key to the Species described in this Paper.

1. Dorsal spine longer than pedicel.

(a) Tendency for thick chitination of cuticle; brachia moderately elevated
longispina, sp. n.

(a¹) Tendency for heavy chitination arrested; brachia greatly elevated
kydia, sp. n.

Dorsal spine not longer than pedicel.

(a) Brachia not longer than anal tubercle, more or less sessile, brachial crater broad 2

(a¹) Brachia longer than anal tubercle, brachial crater narrow *pusana*, sp. n.

2. Row of pores present near mouth-parts *ambigua*, sp. n.

Row of pores absent in the neighbourhood of the mouth-parts ... 3

3. Resin crimson-coloured, terminal antennal segment bulbous.

(a) Anal spine half as long as diameter of crater ... *indica*, sp. n.

(a¹) Anal spine twice as long as diameter of crater *jhansiensis*, sp. n.

***Laccifer longispina*, sp. n. (fig. 1).**

There is a tendency for the oral extremity of the insect to become chitinated, especially the cuticle in the neighbourhood of the mouth-parts. Post-oral lobes present as broad flap-like structures on either side of the rostral setae. Ventral duct clusters partly chitinated. Posterior spiracles present, with the dimples confined mainly to one side, the chitinous plates bearing them not thickly chitinated. Antennae with indications of 2-3 segments, of which the apical segment bears three setae and the one next to it has only one at the side. Brachia not sessile; brachial crater narrow and deep, so that the number of dimples cannot be made out. Nuclear ducts distinct.

Dorsal spine present, with a long pedicel and a slightly curved terminal spine. Gland of the dendritic type also present. Marginal duct clusters of 50 pores arranged along six serpentine areas. Perivaginal pores number 30. Supra-anal plate hispid and the oro-spiracular line prominently thickened.

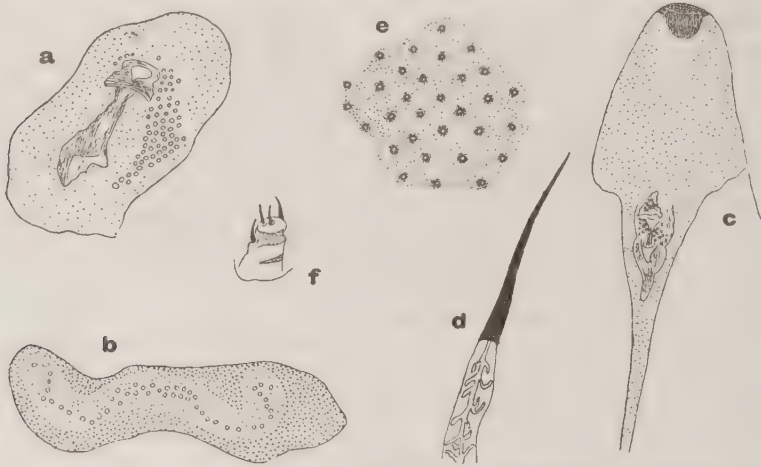


Fig. 1. *Laccifer longispina*, sp. n.: a, posterior spiracle; b, marginal duct clusters showing partial chitinisation; c, brachium; d, dorsal spine; e, ventral duct clusters and their chitinisation; f, antenna.

INDIA: Haflong (J. C. Biswas).

Host plant: Arhal (*Cajanus indicus*).

The tendency for the chitinisation of the cuticle in the neighbourhood of the mouth-parts and along the oro-spiracular line is a marked character of this species. Moreover, the extraordinarily long dorsal spine is a feature of striking interest.

Laccifer kydia, sp. n. (fig. 2).

There is no indication of chitinisation of the cuticle. Mouth-parts present in their usual position and complemented by the presence of the post-oral lobes. Posterior spiracles borne by delicately thickened plates, having the dimples on one side only.

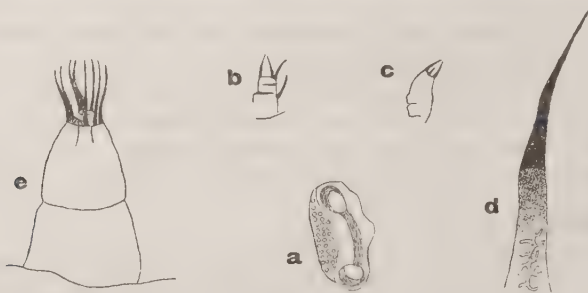


Fig. 2. *Laccifer kydia*, sp. n.: a, posterior spiracle; b & c, antenna; d, dorsal spine; e, anal tubercle, made up of apparently two segments.

Antennae of 2-3 segments, bearing 4 stout setae. Ventral duct clusters, though present, not chitinised. Brachia more elevated than in *L. longispina*. Brachial crater moderately narrow and with 8 dimples; nuclear ducts plainly visible. Dorsal

spine with a long pedicel. Marginal duct clusters present as usual. Supra-anal plate hispid, but the oro-spiracular line only delicately thickened.

INDIA: Silchar (R. N. Dey).

Host plant: *Kydia calycina*.

The tendency for thick chitination of the cuticular structures so marked in *L. longispina* is arrested here. This species differs from the foregoing one also in having the brachia greatly elevated.

Laccifer pusana, sp. n. (fig. 3).

The shape of the insects varies from globular or subglobular to elongated forms, according to the degree of the collateral pressure to which they have been subjected.



Fig. 3. *Laccifer pusana*, sp. n.: a, brachium; b, dorsal spine; c, anal fringe; d, antenna; e, posterior spiracle.

Post-oral lobes present. The antennae appear to be made up of 3-4 segments (although the boundaries of the segments are not clearly defined) surmounted at the apices by three stout and three weak setae. Posterior spiracles borne on thickly chitinated oval discs with the dimples confined mainly to one side. Brachia prominently elevated and longer than the anal tubercle. Brachial crater narrow and bearing marks of 5-6 dimples. Dorsal spine present, with a dendritic gland in association with it and bearing 2-3 tubular spinosities on its pedicel, like those indicated in *L. fici* by Green; the spine is not longer than the pedicel. Anal tubercle shorter than the brachia, but broader than long and hispid. Perivaginal pores aggregated into 10 clusters on either side of the anal tubercle. Marginal ducts disposed along six serpentine areas of 35-40 pores each.

INDIA: Pusa (Rai Bahadur C. S. Misra).

Host plants: Ber (*Zizyphus jujuba*) and Dhak (*Butea frondosa*).

This species is remarkable on account of its greatly elongated brachia, which are longer than the anal tubercle. The anal tubercle is broader than long, and the dorsal spine bears 2-3 spinosities on its pedicel. Moreover, the spine is shorter than the pedicel.

Laccifer ambigua, sp. n. (fig. 4, a, b).

Post-oral lobes present. Antennae without any pronounced indications of segmentation, tipped with 4 setae. Posterior spiracles borne by a chitinous plate with the dimples confined mainly to one side. Ventral duct clusters present; marginal ducts clustered into six serpentine areas each possessing 20-25 pores. Perivaginal pores aggregated into 13-14 clusters on each side of the base of the anal tubercle. A peculiar feature of the specimen is the presence of 22 pores in a row near the mouth-parts external to the antennae, as in *L. meridionalis*. Brachia practically sessile. Brachial crater moderately broad, with traces of 5-6 dimples. Posterior spiracles carried by the respective brachia at their bases. Anal tubercle longer than broad; supra-anal plate hispid. Gland of dendritic type present in association with the dorsal spine.

INDIA : Guna, Jhansi (*Ambika Prasad*).

Host plant : Jheolia.

This specimen is characterised by a few special features. The presence of sessile brachia indicates its affinities with *L. ebrachiata*, while the row of pores near the mouth-parts suggest affinities with *L. meridionalis*; but the combination of both these characters is unique and interesting.

***Laccifer jhansiensis*, sp. n. (fig. 4, c-d).**

Post-oral lobes present. Antennae with a bulbous terminal segment bearing 4 setae apically. Posterior spiracles borne upon rather thick plates, with the dimples confined mainly to one side. No row of pores in the neighbourhood of the mouth-



Fig. 4. *Laccifer ambigua*, sp. n.: a, antenna; b, pores near mouth-parts. *L. jhansiensis*, sp. n.: c, antenna; d, brachial crater; e, dorsal spine. *L. indica*, sp. n.: f, antenna; g, brachial crater; h, dorsal spine.

parts. Ventral duct clusters aggregated into areas round the oral end. Marginal duct clusters sinuate in outline, each with about 45 pores, with a tendency towards a more marked chitination of these areas. Perivaginal pores disposed in the usual manner and 20 in number, ten on either side of the base of the anal tubercle. Brachia nearly sessile; brachial crater fairly wide with 6-8 dimples. Dorsal spine nearly twice as long as the diameter of the crater and bearing some spinosities on its pedicel; a gland of dendritic type is present.

INDIA : Jhansi (*A. B. Misra*).

Host plant : Ber (*Zizyphus jujuba*).

***Laccifer indica*, sp. n. (fig. 4, f-h).**

Post-oral lobes present. Antennae (which in the present case are longer than in any specimen so far examined by me) with feeble indications of three segments and tipped terminally with four setae. Posterior spiracles borne by oval chitinous discs, with dimples confined mainly to one side. Ventral ducts clustered in the usual manner near the oral extremity; while the marginal duct clusters are sinuate in outline, each with about 40-50 pores. Perivaginal pore clusters number 20, ten on each side of the anal tubercle. Brachia somewhat elevated; brachial crater with 6-7 dimples vaguely discernible. Dorsal spine half as long as the diameter of the crater, pedicellated and tuberculated; a gland of dendritic type is present. Anal tubercle longer than broad and the supra-anal plate hispid.

INDIA : Jamunia.

Host plant : Ber (*Zizyphus jujuba*).

This species is much like *L. greeni* or *L. ebrachiata*, but the elevation of the brachia above the surface level immediately separates it from the latter, while the presence of a distinct crater and an anal spine half as long as the diameter of the brachial crater, coupled with the presence of long antennae tipped with four setae, renders it distinct from the former.

ON SOME SPECIES OF GALL-MITES (ERIOPHYIDAE) FOUND ON *CORYLUS AVELLANA*, L.

By A. M. MASSEE,
East Malling Research Station.

(PLATE VII.)

The nut gall-mite (*Eriophyes avellanae*, Nal.) is one of the commonest species of gall-mites that occurs in this country, and it may be found infesting the buds of hazel (*Corylus avellana*) in almost any hedgerow and copse where this plant grows. The species is found also in America and in Continental Europe. Its life-cycle is very similar to that of the black currant gall-mite, *E. ribis* (Westw.) Nal.

During April, May and June, the mites live freely upon the leaves. As soon as new growth is produced, they migrate from the older foliage and enter the newly formed buds of the current year's growth. After some four or five weeks the infested buds commence to swell, and by the end of August the typically enlarged buds, the so-called "big-buds" are plainly visible. The mites remain in the buds throughout the winter. Migration from the "big-buds" takes place during the spring; usually during the latter part of March or in April. The apical buds of the shoots are nearly always attacked, and frequently eighty per cent. of the buds are infested by mites in an abnormal season. Sometimes the buds may be infested without any apparent swelling, but these buds usually dry out in the following spring.

The nut gall-mite attacks the cob nut and filbert in addition to the hazel, and has been recorded as a pest of cultivated nuts by Ormerod and Theobald. Although it occurs in every nut plantation, it has not been considered a pest of economic importance, since infested nut trees appear to produce as many nuts as the bushes not badly attacked. In recent years, however, the mite has become so common in some nut plantations that it is definitely causing damage to the bushes by checking the production of new growth and attacking the female flowers, which after being infested eventually dry up.

During the autumn of 1928 a very bad attack of the nut gall-mite was observed in a plantation near Maidstone. By November, approximately seventy per cent. of the buds were infested with mites, and all the apical buds of the shoots were "big-budded." The damage became more evident later in the year, and by the end of December many of the male catkins were distorted, becoming very rigid and somewhat brittle, and producing little or no pollen. A typical example of an attacked catkin is illustrated (Pl. VII, fig. 1).

Further observations made during February and March, 1929, showed that a high percentage of female flowers were attacked by mites, and it was estimated that up to forty per cent. on some of the bushes were destroyed, but damaged flowers were found on all the bushes. The damage caused to the female flower-buds is similar to that of the leaf-buds. The buds swell up into typical "big-buds" and the deformed red flowers are produced at the base of the galls. Sometimes the flowers dry up prematurely and "big-buds" are not produced. When infested in the manner described above the flowers do not produce fruits. The nature of the attack is shown in Plate VII, fig. 2. Until recently it was considered that the leaf-buds only are attacked by this mite, and Theobald expressed this opinion in 1909 ("Insect Pests of Fruit," p. 308).

Nut growers do not worry about this pest, and very few, if any, attempts have been made to control it in the field. Preliminary experiments have shown that the nut mite may be controlled by spraying the bushes in the spring with lime-sulphur (1 : 30) during the latter part of March or April, when the mites are migrating from the

"big-buds." The lime-sulphur wash did not affect the bushes, but it will be necessary to repeat the experiment before the treatment can be recommended on a large scale.

It has often been said that the nut gall-mite and the black-currant gall-mite are one and the same species. However, this is not the case, since the two species of mites differ very considerably, and the characters for separating them are very pronounced. For instance, there are two pairs of bristles on the thoracic shield of the nut gall-mite, whereas such bristles are not present on the black-currant species. In addition, experiments have been made to ascertain whether it was possible to inoculate nut buds with the black currant mite, and *vice versa*, and in every case negative results were obtained.

Three other species of gall-mites have been found on hazel in this country in addition to *E. avellanae*. They are not regarded as being of any economic importance, but will be dealt with briefly as a matter of interest.

One of these species (*Eriophyes vermiformis*, Nal.) occurs as an inquiline with *E. avellanae* and is found in the "big-buds" during the winter months. During the late spring and summer it lives and feeds upon the lower surfaces of the leaves.

The two remaining species, *Phyllocoptes comatus*, Nal., and *Oxypleurites depressus*, Nal., live upon the under-surfaces of the leaves amongst the hairs. Infested leaves turn brown, but are not injured to any appreciable extent. *O. depressus* is usually found in association with the *Phyllocoptes*. Both species hibernate under the bud scales during the dormant season.

Detailed systematic descriptions of the four species are appended, the descriptions being copied in part from the excellent systematic descriptions of Nalepa.

The photographs were taken by Mr. W. Steer, to whom I tender my thanks.

***Eriophyes avellanae*, Nal.**

1836. *Acarus pseudogallarum*, Vallot, Mém. Ac. Dijon, p. 189.

1889. *Phytoptus avellanae*, Nal., SB. Ak. Wiss. Wien, xcvi, p. 126, pl. ii, figs. 1-3, pl. iii, fig. 3.

Body large, extended. Mature ♀♀ cylindrical. Immature forms worm-shaped. Thoracic shield semicircular, anterior portion truncate, 30 μ long. Shield markings resembling those of *E. tenellus*, Nal. Longitudinal furrows passing through centre of shield. The markings at the posterior margin of the shield gradually bend and turn inwards, away from the lateral edges. Markings at lateral edges consist of long curved lines and shorter markings which extend as far as the base of the bristles. There are two pairs of thoracic bristles: first pair situated near posterior margin of shield, not widely separated, and directed towards lateral margins; 2nd pair situated at about the centre of lateral margins, at same distance apart as 1st pair; 1st pair 17 μ long, rigid, delicate; 2nd pair approximately the same length as claw. Warts of thoracic bristles conspicuous.

Rostrum short, robust. Chelicera 19 μ long, erect. Legs short, stout; 4th and 5th joints short, compact, nearly as long as claw; claws of 1st pair long, 2nd pair hardly as long as 1st. Feathered claw large, generally 4-rayed, sometimes 5-rayed, or occasionally one side 4-rayed and the other side 5-rayed. Bristles of 1st and 2nd pairs of patella of equal length, 2nd pair weaker. Sternal ledge simple, extending as far as the inner coxal angles. First pair of coxal bristles of same length as bristles of patella; 2nd pair before the posterior end of sternal ledge and before the inner coxal angle.

Abdomen moderately broad, symmetrical, marked with coarse punctate rings. The rings of the anal segments of dorsal surface smooth or sparsely punctate. A pair of dorsal bristles present on about the 10th ring from the posterior edge of shield; bristles stiff, 47 μ long, and almost always directed upwards. Lateral bristles inserted

immediately behind the epigynium, very fine, 19μ long. First pair of ventral bristles of same length as 3rd pair; 2nd pair 19μ long; 3rd pair very fine, with tapering ends. Anal lobe broad. Caudal bristles short, whip-like. Accessory bristles thorn-like, somewhat shorter than claw. Epigynium smooth, basin-shaped, 26μ broad. Cover-flap smooth. Genital bristles very fine, directed dorsally, 14μ long.

♀, $250-300\mu$ long, 48μ broad; ♂ 180μ long, 40μ broad.

Host-plants. *Corylus avellana*, L., *C. tubulosa*, Wild., and cultivated nuts; forming the so-called "big-buds."

Distribution. Abundant in the British Isles, Continental Europe, Italy and America.

Eriophyes vermiformis, Nal.

1889. *Phytoptus vermiformis*, Nal., SB. Ak. Wiss. Wien, xcvi, p. 129, pl. iii, figs. 1, 2.

Body markedly worm-shaped; ♀♀ frequently six or seven times longer than broad. Thoracic shield triangular, 30μ long. Shield with three longitudinal furrows in middle, which are bordered by a pair of furrows that are forked at middle and converge as they join the anterior edge of shield. Longitudinal markings at lateral edges not conspicuous, and situate near the anterior margin. Thoracic bristles absent.

Rostrum short, weak. Chelicera erect, 15μ long. Legs short, weak; joints short, 4th joint shorter than 5th. Feathered claw small, 5-rayed. Claw of the 1st pair of the same length as 6th joint; 2nd claw somewhat longer. The outer bristle of 5th joint stiff. Bristle of patella of 1st pair stiff, of same length as 2nd pair of legs. Sternal ledge deeply forked. First pair of coxal bristles placed above anterior end of sternal ledge; 2nd pair before the posterior end of sternal ledge and before the inner coxal angle; 3rd pair very large and of same length as shield.

Abdomen of equal width, evenly ringed and strongly punctate, with 76 rings; 4th ring from anal lobe somewhat broader and smooth on dorsal surface. Lateral bristles very fine, pointing outwards and situated just below the epigynium, 15μ long. The three pairs of ventral bristles fine; 2nd pair very short, 10μ long; 3rd pair hair-like, 21μ long. Anal flap small. Caudal bristles very fine and about twice the length of the shield. Accessory bristles absent. Epigynium basin-shaped, 21μ broad. Cover-flap marked with distinct longitudinal lines. Genital bristles directed towards anal flap, delicate, of the same length as 2nd pair of ventral bristles. Epandrium arched, 15μ broad.

♀ 224μ long, 34μ broad; ♂ 170μ long, 34μ broad.

Host-plant. *Corylus avellana*, L., and cultivated nuts. Usually found in association with *E. avellanae* in the so-called "big-buds." Also found upon the leaves, producing abnormal hairs on the under-surface.

Distribution. East Malling, Maidstone, Kent; Central Europe; Finland.

Phyllocoptes comatus, Nal.

1892. *Phyllocoptes comatus*, Nalepa, Anz. Ak. Wiss. Wien, xxix, p. 191.

Body large, spindle-shaped. Thoracic shield triangular, ornamented with a series of curved lines, and a straight longitudinal furrow passes through the middle of the shield. Thoracic bristles very long, nearly the length of the body, and situated at the posterior margin. Warts of thoracic bristles large.

Rostrum large, partly covered by shield. Legs slender; 4th joint nearly twice as long as 5th joint. Feathered claw 4-rayed. Sternal ledge slightly forked. First

pair of coxal bristles below anterior end of sternal ledge; 2nd pair in line with posterior end of sternal ledge; and the 3rd pair in line with the inner coxal angle.

Abdomen with 34 tergites, which may be smooth or punctate. First pair of ventral bristles of medium length, delicate; 2nd pair a little longer than 3rd; caudal bristles short, accessory bristles absent. Epigynium large, basket-shaped. Coverflap smooth. Genital bristles fine, directed towards anal lobe.

♀, 180 μ long, 60 μ broad; ♂ 120 μ long, 50 μ broad.

Host-plant. *Corylus avellana*, L. Found on the leaves, which turn brown after attack.

Distribution. East Malling, Kent; and Central Europe.

Oxypleurites depressus, Nal.

1894. *Oxypleurites depressus*, Nalepa, Anz. Ak. Wiss. Wien, xxxi, p. 38.

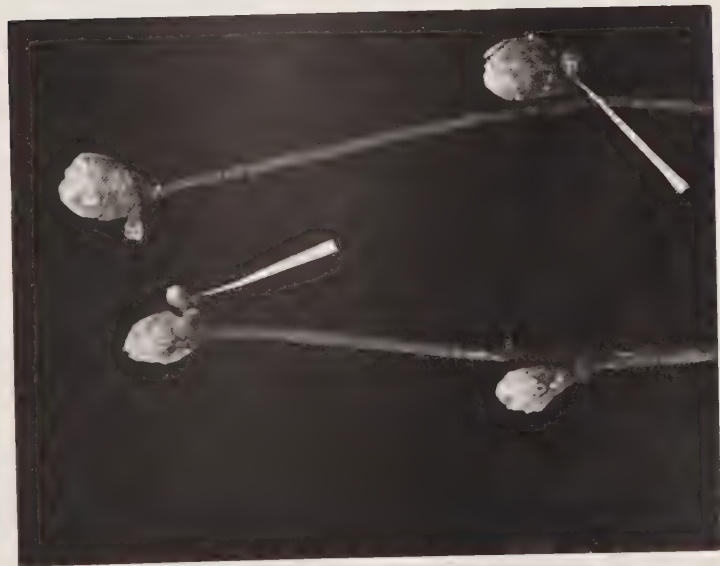
Body frail, small, drawn-out and distinctly flattened. Thoracic shield very large, 46 μ broad, broader than long. Anterior margin projecting, partly covering rostrum. Lateral margins strongly rounded and angled at base. Centre of shield marked by longitudinal curved lines, which are widely separated at base and converge until they meet at anterior edge. Thoracic bristles very short, a little longer than accessory bristles; situated near the posterior margin and placed adjacent to the longitudinal furrows. Warts of bristles very prominent, somewhat folded. First pair of legs 25 μ long; 2nd pair 21 μ long; 4th and 5th joints of legs short, of about equal length. Claw of 2nd pair of legs 7.5 μ long, somewhat longer than claw of 1st pair.

Abdomen very much flattened and strongly tapering towards anal lobe. Dorsum with 15 smooth, broad tergites. Margins of tergites (except the last four) regular, strongly tooth-like. Lateral bristles in line with 1st abdominal tergite, 19 μ long. First pair of ventral bristles 38 μ long; 2nd pair 15 μ long; and the 3rd pair 19 μ long. Accessory bristles very short and fine. Epigynium large, shell-like, 19 μ broad. Coverflap marked with longitudinal lines. Genital bristles directed towards anal lobe, stiff, 19 μ long. Epandrium plain, arched, 16 μ broad.

♀, 150 μ long, 56 μ broad; ♂, 130 μ long, 46 μ broad.

Host-plant. *Corylus avellana*, L. Found on the browned leaves, usually in association with *Phyllocoptes comatus*, Nal.

Distribution. East Malling, Maidstone, England; Central Europe.



Female (left) and Male (right) Flowers of Hazel destroyed by the Nut Gall-Mite.

THE TOBACCO CAPSID (*ENGYTATUS VOLUCER*, KIRK.) IN RHODESIA.

By J. ISGAER ROBERTS, B.Sc.

(PLATE VIII.)

Introduction.

This study was commenced at the beginning of the 1928-29 season with an effort to solve the problem of the transmission of tobacco mosaic in Rhodesia, and chiefly whether any insect vector was responsible. During the whole of the season only a Capsid bug, *Engytatus volucer*, Kirk., was found to be a true denizen of the tobacco plant, feeding and breeding thereon. During the early part of the season a Coreid bug, *Acanthocoris fasciculatus*, F., which is a general feeder on Solanaceous plants, is met with; an Aleurodid is often present but not found breeding; and occasionally a Jassid, *Empoasca facialis*, Jac., is found on the upper surface of the leaves, but is believed only to be a very occasional visitor from cotton growing near the tobacco. During the growing season, which is the rainy period from about November to April, these are the only insects which are likely to act as vectors of virus diseases. There are other insects that cause serious damage to the crop, but these are mainly biting insects, such as cutworms, stem-borers, leaf-miners, budworms, surface beetles, wireworms, grasshoppers and crickets—and none of these has been considered in this study.

The virus of tobacco mosaic is so easily disseminated by various means, such as contact of plants in an infected seed-bed, by the planter's hands during priming or topping, and many other similar ways, the slightest injury to the epidermis being all that is necessary to cause infection, so that it seems relatively easy for all sucking insects to be mechanical vectors from plant to plant. It is not yet clearly established that first infections come from outside sources, and experiments conducted to determine whether infection is possible through the soil after planting and burying mosaic plants in seed-beds have given healthy seedlings; the plants in this trial bed were allowed to grow to a good height without being touched except for watering. Neither is there any evidence to prove the presence of the disease in seed, according to Allard¹; though the virus may be present in all parts of the flower, it is not transmitted with the seed.

In view of these facts and preliminary observations made in this Colony, and that most of the known viruses in plants have been traced to an insect vector, the rapidity of spread throughout the crop at certain periods lends weight to the assumption that tobacco mosaic is carried by an insect. The probability that the initial outbreaks each season were not due to contacts with mechanical or other agencies that necessarily would have to carry over the virus through the seasons, naturally inclined one to believe that an insect would infect the plants either in the seed-beds or in the field. Even where mosaic plants are left in the lands without being stumped, it is seldom that such portions would be visited by the same natives as would be in charge of the watering of the seed-beds. The finding of this Capsid feeding and breeding on tobacco led to great optimism that it would be incriminated as the vector, but this has proved not to be so; though a study of the insect, together with transmission experiments, has revealed it as causing another distinct injury that previously had been attributed to several agencies in the soil.

This species of Capsid is indigenous to the Colony and is distributed generally, but no records have been found of its presence in any other country. Members of the same family are recorded from most tobacco-growing countries as minor pests. Through the kindness of Mr. T. Bainbrige Fletcher, Imperial Entomologist, India, a description of *Engytatus tenuis*, Reut. (*Crassicornis gallobelicus*, Dist.), and an account of

the injury it causes to tobacco have been obtained, and there are great similarities in most respects between the two species. *E. tenuis* is recorded as a minor pest of tobacco in India and Formosa (see Esaki¹²). There are two other species recorded as very injurious to tobacco in Brazil, Mexico and the southern United States,¹⁹ *Engytatus notatus*, Dist., and *E. geniculatus*, Reut. In Porto Rico⁸ *Dicyphus luridus* and *D. prasinus* attack tobacco and other Solanaceous plants throughout the island; also in St. Lucia²⁸ tobacco was practically destroyed by a member of the family CAPSIDAE and cultivation abandoned. In the Dutch East Indies tobacco suffers from Capsids, mainly *Engytatus tenuis* and *Dicyphus nicotianae*. Reports from these countries vary in their estimate of the damage done, but in all there seems unanimity that feeding is injurious, and no mention is made of the possible rôle of the insects as disease carriers.

Tobacco Cultivation.

Tobacco has been grown in Rhodesia for over 25 years. Though both Virginia and Turkish tobaccos are grown, much more of the former is produced; the variety Hickory Pryor is almost universally cultivated for flue-cured leaf, and this variety was the one used throughout this investigation.

The seed-beds are usually made in sandy loams and alluvial soils with good drainage, and then enclosed with brick runs one or two bricks deep at the sides in convenient widths for reaching the seedlings. In Rhodesia the beds are generally burnt over with brushwood or maize cobs which are built up in such a way as to give a burn lasting for 12 to 24 hours. The depth of penetration of the heat is not great and is believed not to be sufficient to kill off any potent virus, such as that of tobacco, if present in any diseased roots or trash which may have been left over from the previous season.

Seeding is done either by hand, mixing the seed in some spreader such as wood ashes or maize meal, the former being preferred, or by spreading with water from finely perforated watering cans, and from this time until the transplants are picked the plants are not touched except for watering. The seedlings are ready for planting out generally about 60 days from the date of sowing, and it is desirable to get the young plants into the field with the earliest rains in November or early December; late planting in January is rarely successful, and in view of the injury to be discussed in this paper is still further to be deprecated. The seedlings are planted out in rows and receive little attention other than "priming" (removal of the small leaves at the base of the plant), "topping" (removal of the terminal bud), "suckering" (removal of the sucker growth from the axils of the leaves), and the usual inter-row cultivation.

Climate plays a very important part in tobacco culture, a moderate rainfall well distributed throughout the growing season being the chief desideratum; plenty of sunshine is also necessary once the plants have established themselves. The plants reach maturity and are ready for harvesting in 90 to 120 days from the time of transplanting into the field. At planting time, dull misty days with frequent showers of rain followed by sunshine to bring on growth are the optimum conditions, and during ripening and harvesting the rainfall should be either very light or finished.

Characteristics of the Plant and Manner of Growth.

The tobacco leaf is covered with dense hairs, each of which secretes a gummy substance that would seem to be a natural hindrance to the smaller insects; but the Capsid in all its stages has long legs and finds the gummy surface no hindrance to its movements, though it must be admitted that the flower-whorls are the more favoured portions of the plant, and these are not so densely coated as the leaves.

The plant can be grown on almost any soil, provided that drainage is good, but soils are important in determining the class of leaf. Most of the tobacco grown is planted on sandy loams of granitic or sandstone origin; soils derived from granite are usually

shallow, and the sandstone soils are much deeper. The sub-soil is also important in determining the yield and quality of the leaf, clayey sub-soils tending to become water-logged and causing the leaf to become dark. The importance of soil will be discussed more fully later in connection with "crinkling." There is one aspect of Rhodesian tobacco soils which may have an intimate bearing upon the susceptibility of plants to attack from sap-feeding insects. Generally most of the tobacco soils are inclined to be shallow, and during ploughing only the top soil is turned over; the sub-soil thus tends to form a hard pan, which has a detrimental effect upon the growth of the plant and renders it more liable to damage by insects.

Description of Adult Insect and Nymphal Stages.

Adult (fig. 1, g). The insect is elongate, the hemelytra having the lateral margins straight and the membrane passing well beyond the abdominal apex. The head has the vertex a pale shiny green, except for the frontal portion which is chocolate-colour; the eyes are black. The antennae are black but coated with minute hairs which give a brown appearance to segments 3 and 4; segment 3 is the longest. The collar con-

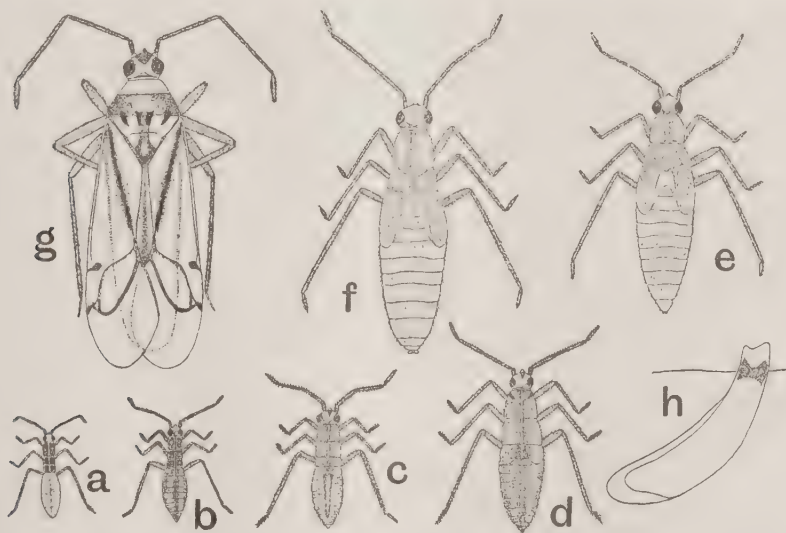


Fig. 1. *Engytatus volucer*, Kirk.: a, on hatching; b, 1st, c, 2nd, d, 3rd, e, 4th, and f, 5th, instars, $\times 10$; g, adult, $\times 10$; h, egg *in situ* in leaf vein, to show amount of cap protruding prior to hatching, $\times 14$.

necting the head and thorax is white, with a light grey carina and brown collum. The general colour of the thorax is rufous; the pronotum has the anterior half light brown and the posterior half shiny grey, with dark markings on the mesonotum showing through; these markings consist of two admedian shiny dark brown patches and a light brown patch on each side; the median area on the scutellum light brown. Coxae light green; rest of leg straw-coloured, with dark tarsi. The wings strongly iridescent and covered with minute hairs, with the claval suture black, the large and small areoles dark grey with smoky patches at the fractures forming the cuneus. The colour of the abdomen varies from light grey to green on the venter and from green to dark grey on the dorsum and sides. Average length, 4.5 mm. to tip of wings.

On Hatching (fig. 1, a). Very pale yellow, semi-transparent, shining; smoky patches on head and thorax. Average length, 1.25 mm.

First Instar (fig. 1, b). Slender, semi-transparent and shining, very faint yellow. Smoky patches on head and thorax. Pale mid-dorsal line extending from base of head, along thorax and abdomen. Head relatively large, with scattered hairs. Eyes deep red, laterally situated and flattened. Abdomen longer than broad, with a row of hairs on each segment. Antennae almost as long as body, pale yellow, all joints with hairs, those on distal segment more dense. Legs long and pale yellow, tarsi tipped dark brown, coxae with smoky patches. Proboscis pale yellow, reaching to posterior coxae. Average length, 1.35 mm.

Second Instar (fig. 1, c). The colour scheme may vary from pale shining green to brighter green, and some specimens have a pale reddish tinge through the head and thorax and the dorsal surface of the abdomen; the ventral surface is pale green. A pale reddish median stripe extends along the head, thorax and abdomen. Eyes deep red. Thoracic segments much larger than in instar 1. Abdomen beginning to show segmentation, median portion convex, sides depressed and showing up segmentation more plainly. Anal protrusion prominent, pale yellow. Antennae with segment 2 longer than 3. Legs long and pale yellow. Rostrum pale yellow, dark brown at tip. Average length, 1.75 mm.

Third Instar (fig. 1, d). Colour varying from pale green to reddish. Wing-pads now visible, slightly paler than rest of body, mid dorsal line with great variation in colour, extending from bifurcation between eyes along thorax and abdomen. Antennae of a smoky colour, with basal segment dark brown. Segmentation of abdomen more marked. Legs pale yellow. Average length, 2.4 mm.

Fourth Instar (fig. 1, e). Wing-pads extending to 2nd or 3rd segment of abdomen, smoky coloured; dorsal surface of thorax with smoky patches, ventral surface pale yellow. Eyes very deep red. Antennae with basal segment deep brown, remainder smoky grey; 2nd segment the longest. Abdomen varying from vivid green to red. Legs pale, with dark brown tarsi. Average length, 3.15 mm.

Fifth Instar (fig. 1, f). Colour varying from bright green to reddish. Wing-pads extending to end of 4th abdominal segments and smoky. Second and 3rd antennal segments about equal in size. Mid dorsal stripe extending throughout thorax and abdomen. External genitalia visible. Eyes dark brown. Average length, 3.75 mm.

Life-history.

This insect is easily reared in captivity, the nymphs having been kept on a young tobacco plant under a glass chimney. As the main object of the investigation was to find out whether this particular insect was a vector of tobacco mosaic, the insects were fed on mosaic leaves in petri dishes, where they thrive, except for cannibalism.

The life-cycle is rather short. The first moult takes place after about three days, and the 2nd, 3rd and 4th moults average about two days, whereas the 5th moult usually takes from three to four days. At the beginning of the season the cycle is shorter than at the onset of the cold weather and occupies from 12 to 14 days from the time of hatching. The adults have been kept in captivity for periods of eight to ten days. Towards the end of the season all stages are lengthened out, and the total life-cycle may occupy from 20 days upwards, with an average of about 22 days. Generations follow each other uninterruptedly, and during the tobacco-growing season in the field, which usually occupies from 90 to 120 days before picking commences, there may be expected at least four generations. The fertility of the females must be great, though the number of eggs laid by each is not very satisfactorily established; as many as 16 eggs have been found in one midrib.

The Egg and Oviposition.

The egg (fig. 1, h) is opalescent and glistening, and the surface minutely honeycombed. The cap shows no differentiation in colour from the rest of the egg, neither are there any

filaments, such as frequently occur on Capsid eggs, but there are two small processes which are usually on a level with the epidermis. The egg is not easily seen except by removal of the epidermal layer, when it usually becomes detached from the inner tissues but remains attached by the cap to the epidermis. On an average the egg measures 1 mm. in length, with the lower end rounded, and tapering slightly towards the cap. The eggs are found in all the softer tissues but mostly in the midrib of the leaf and in the young stems of the top whorl of the flower-buds; they occupy an almost vertical position to the plane of the surface and occur singly, though clusters of two or three are often met with. The detection of the eggs from the upper surface is most difficult, as the puncture is hidden by the dense mat of hairs with their gummy exudation.

Oviposition has been observed to commence in January and is carried on throughout the whole of the tobacco-growing season without interruption, but is at its highest during April, when the greatest numbers of insects are to be found. Females which have been kept under observation for egg-laying have been found to be careful in choosing a site, inserting the proboscis for very short intervals at several places but not feeding. The whole operation occupies about three minutes.

The ovipositor is composed of four blade-like parts, the outer pair almost completely covering the inner pair. The outer sabre-shaped blades are much serrated and end in heavily chitinated fine points. Two pairs of apodemes act as levers to the ovipositor.

When the eggs are first inserted they are completely embedded in the tissue but gradually move forwards until about a quarter protrudes above the surface just prior to hatching. At hatching most of the egg-shell protrudes from the surface, and when the slit takes place a pale yellow nymph emerges, which remains quiescent near the egg-case for some time before starting to search for food.

The hatching of the egg requires moisture, and it has been observed that when tobacco leaves were kept in potato dishes the percentage of successful hatching was much higher than when the petioles and stems were placed on soil within muslin cages.

Oviposition does not seem to be confined to any particular time of day, but has been observed at various times; the adults are always most active during sunshine, and it is believed that most of the egg-laying is carried out at this period.

The incubation period appears to range from 3 to 8 days, but was accurately determined in only two cases, which took $3\frac{1}{2}$ and $4\frac{1}{2}$ days respectively.

Habits of the Adult.

The Capsids are the only members of the Hemiptera which have been found to be true denizens of the tobacco plant in Rhodesia, both feeding and breeding on it during the whole of the growing season after the appearance of the first inflorescence; but with late-planted tobacco the young plants are attacked before the inflorescences appear and even when these have been destroyed during the operation of "topping."

The adults are very active and fly readily when disturbed, and during the daytime pass from plant to plant. They have also been taken from the windscreen of a motor car and in a room at night time, so that the range of flight must be considerable.

They are not gregarious during any stage of the life-cycle; all stages may be found on different parts of the plant, but the inflorescences and the midribs of the leaves are the most favoured parts both for feeding and oviposition.

The feeding of *E. volucer* is not confined to the tobacco plant, it may at times be both cannibalistic and carnivorous. If several of the insects are confined in glass jars, it will be found eventually that only one remains, and any of their own species that may be weakened or otherwise inactivated will be readily fed upon by sucking the abdominal contents. This phenomenon has also been observed under natural conditions in the field. The gummy nature of tobacco leaves makes them a ready trap

for most of the smaller insects, and on these the Capsid has been seen feeding, even though many of them were still alive.

The insects feed on all parts of the plant, and both the upper and lower surfaces of leaves may be utilised, though preference is shown for the young leaves and stems ; but the actual feeding site seems to be carefully chosen, as the proboscis tests the surface several times before the mouth-parts are finally driven into the tissue. One female was observed to test the surface at twelve different spots before finally settling down to feed, which act occupied seven minutes.

The adults hibernate in or near tobacco fields, though no definite host-plant has been observed. They have been found on grasses and in buildings during the cold weather.

No other host-plant than tobacco has been found during the summer months.

In all stages the nymphs are active feeders, but are mainly confined to the inflorescences and the veins of the leaves. They are of retiring habits and scatter with the least disturbance to hide on the undersides of leaves.

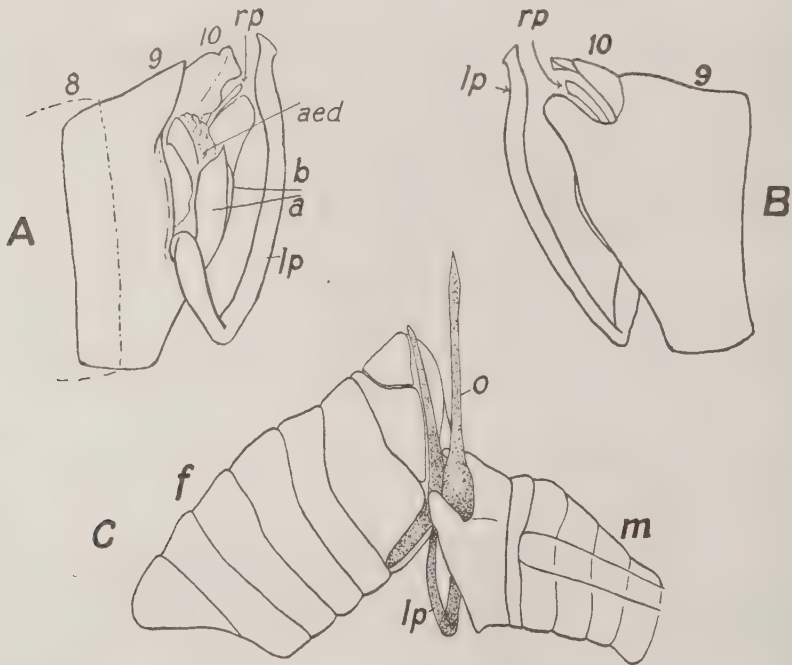


Fig. 2. *Engytatus volucer*, Kirk. : A, lateral view of left side of ♂ genital segments ; B, lateral view of right side of ♂ genital segments ; C, position of insects during copulation, left side of ♀, right side of ♂ ; *rp*, right paramere or genital style ; *lp*, left paramere ; *a*, and *b*, left and right ventral plates of pygofer ; *o*, ovipositor ; *aed*, aedeagus ; *f*, female ; *m*, male ; 8, 8th abdominal segment ; 9, 9th abdominal segment, or pygofer ; 10, anal segment.

Copulation and Anatomy of the Parts engaged (fig. 2).

The most interesting part of the life-history of this Capsid is in connection with copulation and the parts functioning during this act ; no literature has been found which gives any clue to the functions assumed by the various parts. The paper by Singh-Pruthi²² on the morphology of the male genitalia in Rhynchota does not give the functions of the asymmetrical parts of the male, and only examination of pairs

killed *in copula* has been of any value, so that the interpretation given in the following account is entirely that resulting from observation.

Copulating pairs have been studied immediately after being killed and again after clearing in potash. After disengagement the parts to a great extent resume their natural positions, except the penis, which remains outside but in a collapsed state as compared with what is seen immediately after death. The female genitalia are quite normal; the diamond-shaped genital opening is situated at the base of the 8th segment and tapers at both ends to fine points; the ovipositor arises from the 8th segment and curves so as to lie within a groove to reach the anal protuberance. The ovipositor is operated by muscles attached to the two pairs of apodemes, and during oviposition the curved bases are brought to lie over the base of the 8th segment, where it receives the eggs for deposition.

The male external genitalia* are asymmetrical with the exception of the aedeagus or penis. The 9th abdominal segment, or pygofer, is produced on the right side into a fairly large process, round at the apex, and arising from near the base of the anal segment; the ventral margin curves upward and is produced into two subangular plates; on the left side there is a deep sinus, at the bottom of which arises the left paramere. This paramere is long, fairly slender and bent about one-third from its base; when at rest it lies upon the large surface of the curved-up portion of the pygofer, where there is a shallow depression to receive the basal portion. The right paramere is very small, and evidently rudimentary; it arises from the membrane at the base of the projecting portion of the right side of the pygofer. The aedeagus (basal plate and phallosoma) is small and strongly sclerotized on the dorsal surface; there is a large complex internal sac (endosoma of Singh-Pruthi), which is folded up and packed away within the aedeagus when at rest. Its exact size and shape was not made out, a large portion of its surface being covered with scale-like, flattened spines; whether there be a distinct vesica within this bearing the gonopore was not made out. This internal sac is protruded and distended by blood pressure during copulation and forms the intromittent organ. The distended sac prevents uncoupling until blood-pressure is relaxed.

Asymmetry is general in the genitalia of this group of Heteroptera, especially in the parameres, but so far as is known the present case is extreme.

During copulation the genitalia are closely approximated and only when slightly separated can the relationship of the parts be plainly seen. The base of the ovipositor fits into the anal groove of the male and is clasped on each side by the ventral plates of the pygofer, whose function seems to be the slight raising of the ovipositor in order to approximate the penis to the female genital opening; a leverage is also obtained for the male. These plates also apply pressure for the extrusion of the penis.

The function of the left paramere is not so readily understood. It arises on the left side of the male, but being elbowed comes to occupy a median path, though during copulation it lies on the left side of the penis and the tip only enters into a fold of tissue which lies between the female opening and the base of the ovipositor. The fold into which the spine enters is darkened on the edges, and there seems to be an opening for the reception of the spine; further, the track occupied by the spine along the side of the segment is grooved and glossy, denoting continual movement or friction. It is tentatively suggested that the function of this paramere is to act as a stimulating organ for the female; it certainly does not take any part in the act of copulation and apparently has no clasping function.

Copulation has been observed to take place for three hours, and at its conclusion disengagement is very abrupt. In one case the male travelled a short distance away and after a short while inserted its proboscis within the genital opening, the abdomen

* [Mr. F. Muir has very kindly rewritten the description of the male genitalia, and fig. 2a and b were drawn by him.—ED.]

being completely flexed to meet the proboscis ; this position was maintained for ten minutes. After relaxing the abdomen a large blob of yellow liquid was passed. The explanation of this action remains uncertain, unless such a process is necessary for the insertion of the penis within the highly chitinised repository. The female after the act of union remained for some time cleaning its genitalia with the hind legs and then rested for about two hours before feeding.

Percentage of Sexes and Rate of Increase.

In counts made during the early part of the season the proportion of females to males is much higher, but later there is a balancing of sexes. At the onset of the colder weather the females are again in a higher ratio, and in this proportion the sexes prepare for overwintering.

As previously mentioned, the rate of increase is very rapid after the appearance of the first inflorescences, and the infestation is greatest when there is a heavy call upon the resources of the plant. It is difficult to ascertain definitely the numbers of eggs laid by individual females during their life-cycle ; dissections made of pregnant specimens gave numbers ranging from 10 to 35 in various stages. The average number of ripe ova nearly ready for extrusion was 10, though there seem to be long intervals between the deposition of the eggs. The highest number of eggs found in any one leaf was 18.

Transmission Experiments with *Anthocoris fasciculatus*, F.

This Coreid bug was the first Hemipteron observed on the tobacco plants. Six plants which had been kept over winter were found with two or three of these insects feeding on the stems and leaves. The plants were about two feet high at the time (3rd December) and were beginning to show signs of growth after the winter. Another plant near by which had mosaic bore no insects.

3.xii.1928. Insects removed from healthy tobacco plants and transferred to the mosaic plant.

16.xii.1928. Insects removed from mosaic tobacco plant, transferred to six healthy seedlings, and covered over with muslin cages.

2.i.1929. Insects released and plants examined. No signs of disease present in any of the plants. All plants treated with liquid nitrate of soda to bring out mosaic symptoms if present.

18.i.1929. Six plants examined and found to be quite healthy.

Though the insects remained feeding on the plants and had also deposited eggs in some instances, no injury whatever was observed as a result. The absence of insects from the adjacent tobacco plant affected with mosaic is in no way unusual, because such diseased plants are not favoured for feeding. It is rather strange that such a large insect has no injurious effects upon the plant, and though obviously contaminated with mosaic virus after its long sojourn on the mosaic plant has failed even to act as a mechanical carrier.

Experiments with Aleurodidae.

An unidentified species of Aleurodid occurs on all the crops grown at the Experimental Station. It does not specially favour tobacco and only occasional specimens are met with on it ; it has not been found breeding on this plant. The Aleurodids were captured on mosaic tobacco plants by means of a pipette and rubber tube into which they were sucked.

13.iv.29. Aleurodids collected from mosaic tobacco plant and transferred to healthy seedlings under glass chimneys : four seedlings with one insect to each plant ; four seedlings with three insects to each plant ; three seedlings with four insects to each plant.

24.v.29. Plants inspected after removal from chimneys; none showed signs of injury or mosaic disease.

31.v.29. Plants finally inspected and all healthy.

Experiments with *Empoasca facialis*, Jac.

This Jassid is not a true denizen of the tobacco plant, but individuals are frequently met with on tobacco grown in the vicinity of cotton. Some of the Jassids were collected from cotton and others from tobacco and transferred to healthy seedlings. They were kept in glass cages, similar to those used in studying the life-history of this insect on cotton.

Experiment 1.

12.ii.29.	Tin 20	Jassid nymph introduced from Bancroft Cotton.
	22	„ adult „ „ „ „
	23	„ nymph „ „ „ „
	25	„ nymph „ „ „ „
	28	„ adult „ „ „ „
19.ii.29.	Tin 20	Nymph dead. Plant healthy.
	22	Adult alive. Leaf area yellowing and spreading in leaf.
	23	Nymph dead. Plant healthy.
	25	do. do.
	28	Adult alive. Leaf dying, yellowing spreading beyond area of tube.

Experiment 2.

12.ii.29. Five adult Jassids from mosaic tobacco leaves placed separately on healthy seedlings.

19.ii.29. All the leaves where these adults had fed turned either a pale yellow or colourless. Four of the insects remained alive. The effect of Jassids feeding upon tobacco results in a destruction of the chlorophyll.

19.ii.29. Liquid nitrate of soda applied to plants.

10.iv.29. No mosaic or other virus symptoms developed. Cold nights were experienced and the treatment with nitrate should have brought out any mosaic symptoms if present.

The results from this experiment are interesting in that nymphs do not survive any length of time on tobacco foliage, though the adults all lived, except in one case, for seven days. No symptoms of injury developed on leaves where nymphs had been confined, but with the adults all the leaves yellowed, though no crinkling or puckering took place.

In view of these results the paper by Carter & Crawford⁷ on *Eutettix tenella* injuring tobacco is rather interesting, this insect being the well-known vector of curly-top disease of beets, a virus disease. The result of the feeding of this insect causes tobacco plants in America to become badly stunted and dwarfed, with the leaves curled—a condition similar to curly-top. When non-infective *E. tenella* were caged on these plants and removed from them to healthy beets, the latter developed typical symptoms of curly-top. But juice extracted from diseased tobacco plants and inoculated into healthy tobacco produced no effects. This result is rather surprising in view of the transmissibility of most viruses by inoculation.

Experiments with *Engytatus volucer*, Kirk.

The original experiments conducted with *Engytatus volucer* were simply caging of the various stages upon tobacco leaves for testing the possibility of the insect acting as a carrier of virus diseases. But the results indicated another form of injury, which necessitated further work to find out its exact nature.

Experiment 1.

11.ii.29. Four adult Capsids and four nymphs were caged in tubes separately on young tobacco leaves. Six tobacco seedlings were kept as controls.

- 19.ii.29. No. 1. Adult dead, area within tube dying.
 No. 2. Adult dead, area within tube dying and leaf flaxen.
 No. 3. Nymph alive, plant slightly withering.
 No. 4. Nymph alive, plant healthy.
 No. 5. Nymph alive, plant healthy.
 No. 6. Adult dead, necrotic spot inside tube.
 No. 7. Adult dead, leaf area within tube dead.
 No. 8. Nymph moulted to adult. Plant dead.

All controls remained healthy.

In seven plants out of eight the leaves became curled and puckered, but no mosaic symptoms were showing. The crinkling, which is the best descriptive term for the symptoms, was present in the leaves only where adults had been feeding, but where nymphs had fed the whole of the young plant showed slight symptoms.

Experiment 2.

This experiment, carried out on 5.iii.29, was to ascertain the length of time during which the tobacco mosaic virus remains active after several punctures had been made into tobacco plants. The virulence of tobacco mosaic is already known; it may last several months in solutions made from crushed leaves or in dried leaves. It was thought that, if this Capsid acted as a carrier of mosaic, once the proboscis had become infected transmission might be possible to several plants in succession.

A sterilised needle was passed through the veins and lamina of a freshly crushed mosaic leaf and then pushed into the vein of one leaf of each plant in succession. Six plants were used, and mosaic symptoms developed by 11th April in the first, second, third and fourth plants, in that order, whereas the fifth and sixth remained free.

No account has been taken of the enormous difference in area of the surfaces of an ordinary dissecting needle and of a Capsid proboscis, so that no comparisons can be made. It is chiefly interesting in showing how many plants can be inoculated with such a potent virus even from one contact.

Experiment 3.

No. of Plants.	No. of Injections.	Type of Inoculum.	Results.
3	4	17 adults macerated in 2.5 cc. distilled water.	Slight rolling of leaves. Crinkling and clearing of veins in older leaves. No mottling. Young leaves remained healthy.
3	4	15 adults; thorax macerated in 2.5 cc. distilled water.	Rolling and crinkling of leaves. No mosaic.
3	Each leaf except growing shoot.	15 adult abdomens macerated in 2.5 cc. distilled water.	No symptoms.
3	4	17 adults macerated in 2.5 cc. 25 per cent. alcohol.	Slight crinkling of leaves.
3	4	25 nymphs macerated in 2.5 cc. distilled water.	No crinkling, slight clearing of veins.
3	4	25 nymphs macerated in 2.5 cc. 25 per cent. alcohol.	No symptoms.
2	1	1 nymph crushed into vein of leaf.	Healthy.

In all experiments, at the point of inoculation, necrotic lesions were produced.

Experiment 4.

8.iii.29. The proboscises of three adult Capsids were cut off and pushed into the main vein of three leaves in different plants with a flame-sterilised needle.

11.iv.29. No mosaic symptoms. At the point of insertion the tissue was blackened, otherwise the plant remained healthy.

Experiment 5.

8.iii.29. The thorax was cut off from five adult Capsids and pushed into a slit made in the leaf vein of five plants, using a flame-sterilised needle.

11.iv.29. The plants were examined and found to be healthy except for crinkling occurring in all the leaves which had a thorax inserted, and slight symptoms appearing in other leaves.

Experiment 6.

8.iii.29. The ovipositors from three females were cut out and pushed into a leaf vein of three different plants.

11.iv.29. No signs of disease or injury, plants remained healthy.

Experiment 7.

8.iii.29. Inoculum made from a crinkled tobacco plant in the field and scratched into the haulms and leaves of three healthy Up-to-Date potatoes, part of inoculum also injected into the haulms. Also repeated with three healthy tomato plants.

11.iv.29. Both potatoes and tomatos remained healthy and showed no signs of injury, except for necrotic lesions at point of insertion of needle.

Experiment 8.

18.iii.29. Inoculation experiments with macerated Capsids.

No. of Plants.	No. of Injections.	Type of Inoculum.	Results.
A. 4	2	Thorax from 50 adults macerated in 3 cc. distilled water.	10.iv.29. Quite healthy, but all leaves of plant were showing signs of crinkling.
B. 4	2	Abdomens of 50 adults macerated in 3 cc. distilled water.	10.iv.29. Quite healthy; no crinkling occurred.
C. 4.	2	32 nymphs macerated in 3 cc. distilled water.	10.iv.29. Quite healthy; very slight crinkling in younger leaves.

All the plants in (A) and (C) later developed more severe signs of crinkling and remained stunted.

Experiment 9.

27.iii.29. In this experiment it was attempted to concentrate Capsids taken from mosaic tobacco plants on young seedlings. The plants were covered by glass chimneys.

10.iv.29. The five plants used were found to have only one adult female remaining, this being due to the cannibalistic nature of the insects.

2.iv.29. A further experiment was commenced, using only the early stages. Better success attended this attempt and slight crinkling was produced in the plants by 3rd May.

Nature of Damage to the Plant done by the Capsid.

The result of the feeding of large numbers of Capsids and also of injections made from thoracic contents is to cause a rolling of the leaves and the surfaces become puckered and uneven, the best term to denote this injury is "crinkle." Plate VIII, figs. 1 and 2, will give a better idea of the resulting damage, one from a plant in the field and one which has been injected with the thoracic contents.

There are two forms of injury arising from the feeding of these Capsids. Firstly, the selection of a feeding site causes the plant to be punctured in several places and the serrated mandibles thus cause considerable injury to the tissue by laceration of the cells. There is a collapse of the surrounding cells, which gives a shot-hole appearance to the leaf and will naturally reduce its commercial value.

The second form of injury and also the most important is the action of the escaping saliva in spreading into neighbouring cells from the seat of the original puncture. All the tissue in the vicinity of the puncture suffers, and apart from the effect upon the health of the plant, the collapsed areas cause a contraction of the leaf surface in various places which gives the crinkled appearance to the leaf. Though the crinkle in the leaf is the most injurious from the tobacco-grower's point of view, the veins and the stems suffer equally and the plant is stunted.

The Capsid population is important in its bearing upon the extent of the injury in the field, because the insects reach the peak in numbers during April, and thus early planted tobacco will not have been affected to the same extent as that planted later. The preference shown for the young growth for feeding, if the infestation was at its height during the first months of planting in December and January, would cause a much greater loss through crinkling and stunting of the plants. With a crop that has yielded good leaf, the plants which remain in the field have a number of the upper younger leaves and the inflorescence badly crinkled, these parts being the only ones to suffer heavily at the height-of infestation.

Crinkling has been formerly associated with a poorly functioning root-system, such as a bent tap-root or the striking of a hard pan, and this is in accordance with observations in the field on crinkle. Such plants growing under adverse conditions are weakened and are the first to show symptoms of attack. Hopkins¹⁵ has observed that crinkled plants are more common on ant-heaps than upon normal soil; in this case there would be insufficiency of water to cause the initial weakness.

The progress of the injury in the field will be governed to a great extent by the conditions of growth and especially the soil. Usually on granite or contact soils the surfaces are shallow, from 4 to 8 inches in depth; besides many of these shallow soils have a stiff clay sub-soil. Root growth is hampered when it strikes these clayey sub-soils, and also water-logging occurs, causing a condition known as "wet feet." The nature of the sub-soil is of immense importance regarding yield and quality of leaf grown; further the important part it plays in the health of the plant influences the number of plants which will suffer from crinkle, plants grown under favourable soil conditions being much less liable to suffer from Capsid attack.

Most of the other types with similar symptoms are associated with mosaic disease, the latter being easily recognised when present as a mottling with variations in the green colour of the leaf. With mosaic the growth of a plant is checked and the leaves are short, narrow and thin, but crinkle makes the leaves thicker with the typical surface puckering, but no variations in colour occur.

There is some evidence available that unsuitable soil conditions in the field will cause stunting and a slight puckering of the leaves. In laboratory experiments where tobacco seedlings were raised in 10-inch flower-pots, the plants that were injected with the solution from crushed insects alone showed symptoms of crinkle, the leaves of other plants used as controls remained normal, though the plants did

not grow to any great height. The depth of soil for root penetration is small compared with that normally available under field conditions, but even so no crinkling has developed.

It has been observed that with young plants heavily infested with the aphid, *Myzus persicae*, Sulz., there is a dwarfing of the plants and the outer margins of the leaves roll downwards; this has only been observed under artificial conditions.

Discussion and Conclusion.

Originally this study was carried out to ascertain whether *E. volucer* was capable of acting as a vector of tobacco mosaic. This has not been found to be the case, though another injury results from the toxic nature of its saliva. After finding that a rolling and puckering of the leaves took place, a consultation of literature showed that Capsids are reported as injurious to tobacco in most parts of the world. Most of the notes have been obtained from summaries in the *Review of Applied Entomology*, the original articles not being available.

From the descriptions available of the damage to the tobacco plant in the U.S.A. and Brazil, the injury is associated with yellowing (which is taken to indicate that the whole of the leaf loses colour) and the subsequent drying and wilting. The description of the injury as observed in India is more in accordance with observations in this Colony; the leaves show irregular pale blotches, which are translucent when the leaf is held up to the light, and in some cases the injury results in the leaves being crumpled and generally uneven.

The injury to the tobacco plant is caused solely by the poisonous nature of the saliva, and it is very interesting to find that the insect is not a vector of tobacco mosaic. Smith²⁴ mentions, with reference to *Plesiocoris rugicollis* on apple, that "after the insect's stylets are withdrawn a drop of fluid exudes from the puncture and slowly grows in size as the cells below are killed and give up their contents." No such exudation or any accumulation of saliva at the seat of puncture has been observed with any of the Hemipterous insects studied in this country. It seems probable that a higher rate of respiration occurs in cultivated plants in Rhodesia, so that the translocation current will also be faster and the salivary fluid forced into the plant will be taken up by the current and passed into a larger area of the leaf. The result of this rapid passage of the saliva will show, not localised atrophied cellular tissue to the extent observed by Smith, but a general effect throughout the lamina of the leaf, and in the case of tobacco a general puckering of the tissue. The 'shot-hole effect' is not so pronounced in tobacco leaves, and only when areas which have been fed upon are held up to the light can the paler patches be observed.

Hopkins¹⁵ states that "observations go to show that the immediate origin of trouble (crinkle) is a poorly functioning root system" and that "in the majority of cases diseased plants have little or no tap-root." Plants weakened by such causes, due to striking stones, or poorly cultivated soil and growth on ant-heaps, are naturally more liable to suffer when attacked and usually show the symptoms of crinkle in a much worse form than plants growing under favourable conditions. Hopkins also mentions that "crinkle appears after a plant has been attacked by stem-borers (*Phthorimaea heliopa*, Lwr.)," and that "the presence of stem-borer should be sought in the case of crinkle." The experimental production of crinkle, in the absence of any other insects, by the action of the salivary glands from Capsids proves that the toxic nature of the saliva is the only cause; plants grown under similar conditions as controls and injected with distilled water never became crinkled.

The control of the insect lies chiefly in cultivation and the choosing of suitable sub-soils. Tobacco should be planted early so as to be well established by the time the infestation is heaviest during April.

Summary.

1. The Hemipterous fauna of the tobacco plant in Rhodesia during the growing season is confined to a Coreid, Aleurodid, Jassid and a Capsid.
2. A description of the adult and various instars of the Capsid, *Engytatus volucer*, Kirk., is given.
3. The habits of the insect on tobacco are discussed.
4. Attempted transmission of tobacco mosaic by Hemiptera found on tobacco plants failed.
5. Further experiments with the macerated contents of the thorax of *E. volucer* have proved it to cause a rolling and puckering of the leaf surface, which is termed "crinkle."
6. Crinkle is caused by the poisonous nature of the saliva which spreads rapidly through the interior of the leaf. The salivary action does not affect localised centres to any appreciable extent so as to cause a "shot-hole" effect, as observed with other Capsids. The feeding sites are only noticeable when the leaf is held up to the light; rapid translocation currents cause its action to be spread over larger areas.
7. The injury is aggravated in weakened plants grown under adverse conditions, such as the striking of a hard pan in the sub-soil or a stone, or water deficiency.
8. Control can be effectively carried out by thorough cultivation of the soil, and the choosing of suitable sub-soils for root development. Early planting in December is recommended, or even earlier if rains are suitable, so that the plants will be well established before the height of infestation in April.

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A plant crinkled under natural conditions.



Tobacco plant with leaves crinkled after injection of thoracic contents of *Engytatus volucer*, Kirk.

ON THE ETHIOPIAN SIMULIIDAE.

By BOTHA DE MEILLON, M.Sc., F.E.S., W*South African Institute for Medical Research, Johannesburg.*

The object of this paper is to supply a means to the worker in the field for determining the SIMULIIDAE that he may collect, with reasonable accuracy, until such time as he can have them identified by a systematist. A key to the females is given, and Mr. A. W. J. Pomeroy's figures of male genitalia and pupal filaments are reproduced. In this connection the worker is urged not to depend solely on the key to the females, which could no doubt be greatly improved upon when more material is available, but to make use of the figures of male genitalia and pupal filaments where possible.

Very little is known about the early stages of these flies in the Ethiopian region, especially the larvae, of which none has been accurately described. The difficulties of rearing the immature stages in the laboratory has, no doubt, much to do with this gap in our knowledge. The larvae and pupae of all species known so far are found only in running water and die as soon as they are removed to the ordinary breeding receptacle used in the laboratory.

Newstead¹⁶ has found that if the pupae are placed in a humid atmosphere, e.g., on damp blotting paper, with all excessive moisture removed, the adults will emerge quite well. Puri¹⁹ has succeeded in rearing the adults from the egg without much difficulty. He considers aeration of the water and an abundance of food supply to be the main factors in the process. The water was aerated by a blower attached to the laboratory tap.

The correct correlation of the larvae and pupae with the adults is necessarily very important, but also rather difficult. Edwards⁶, however, has suggested the following method of getting over the difficulty. "In a colony of larvae where even a moderate proportion are full-grown, some are sure to be found which exhibit a round black spot on each side of the prothorax, conspicuous even to the naked eye. This is the respiratory organ of the developing pupa showing through the larval skin, its component filaments being coiled up into a small space. The filaments can be very easily dissected out with a pair of needles, and a positive identification of the larva and pupa obtained. If in the same colony there are also blackish, well developed pupae, the species can be identified by dissecting these without the necessity of waiting for specimens to hatch out. It is very desirable to identify larvae by this reliable method, since one very frequently finds several species living together in the same colony; though in a small area of a few square inches one will usually outnumber the others."

Information on the habits of the Ethiopian SIMULIIDAE is also very scanty; such as I have been able to gather is recorded below.

SIMULIIDAE were at one time suspected of being concerned in the transmission of pellagra. This disease, however, is now believed to be of dietary origin.

Blacklock³ has shown that *Simulium damnosum* is the vector of the Nematode, *Onchocerca volvulus*, and workers in South America suspect SIMULIIDAE of playing a part in the transmission of the closely related *Onchocerca caecutiens*.

These flies have been reported as causing grave loss to live-stock from many parts of the world. Schmidt²⁰, for instance, working in Hungary, reports the swarming of SIMULIIDAE which subsequently killed cattle, donkeys, horses, pigs and sheep, the bitten animals dying in from one to two hours after being attacked. Lea¹³, in Australia, writes of the annoyance these flies cause to domestic animals. Bang², in

Sweden, Miessner¹⁵, in Germany, and numerous American authors, all give evidence on similar lines. Fuller⁹, working in South Africa, appears to be the only one who has recorded SIMULIIDAE as attacking domestic animals in great numbers. Austen¹,

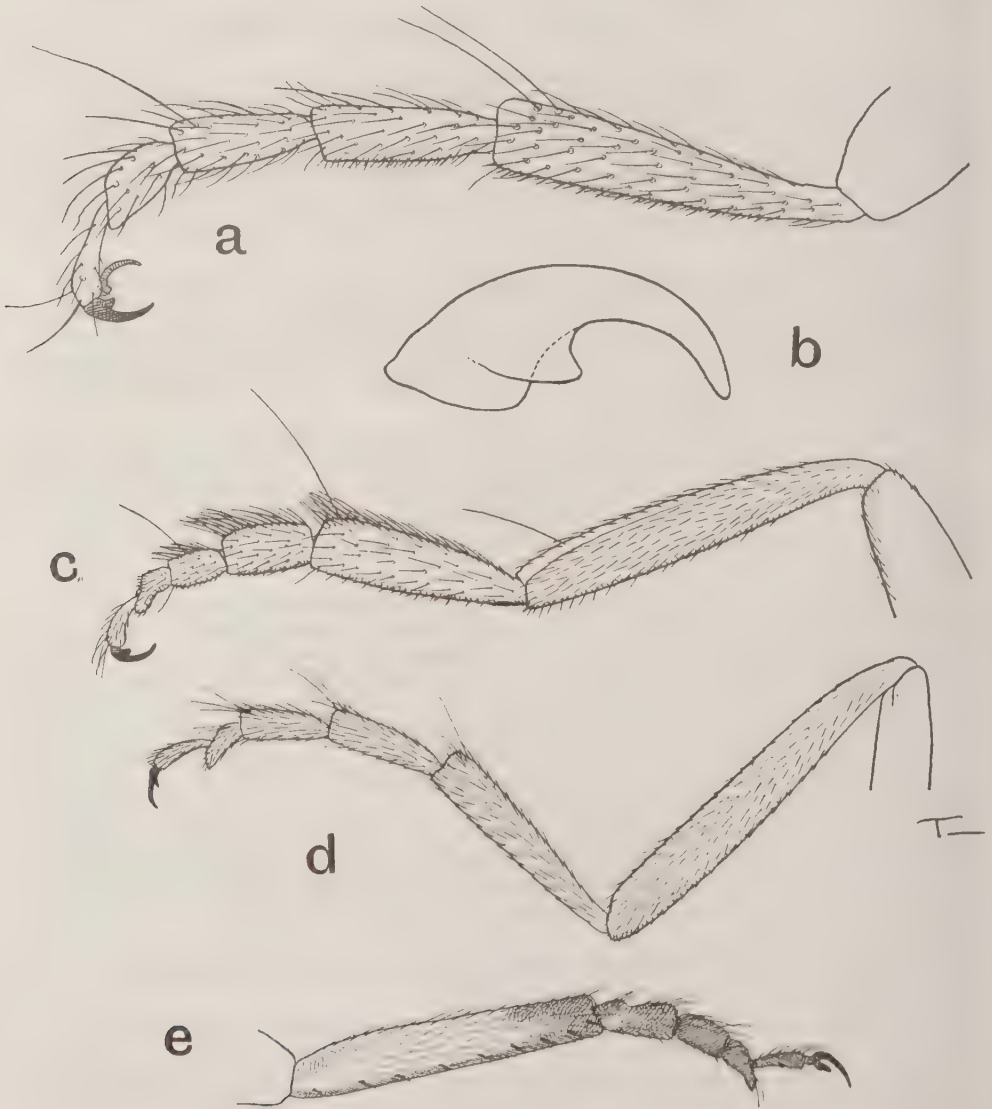


Fig. 1. a, *Simulium bovis*, sp. n., front tarsus; b, *S. dentulosum*, Roub., tarsal claw; c, *S. damnosum*, Theo., front tibia and tarsus; d, *S. neireti*, Roub., front tibia and tarsus; e, *S. griseicollis*, Becker, hind tarsus.

in his "African Blood Sucking Flies," also records these flies as attacking human beings and animals. Nothing, however, comparable to the loss recorded from Europe has been reported from the Ethiopian region.

The deaths of animals after having been bitten by SIMULIIDAE is said to be due to poisoning from the salivary glands of the insects (Bang, Meissner). In this connection Georgévitch¹⁰ performed some interesting experiments. He extracted a poison from the heads of the flies, and on injecting it under the skins of guinea-pigs, rabbits and white mice, found it to be virulent, but animals surviving the initial dose developed a certain amount of immunity to subsequent injections.

The SIMULIIDAE have been divided into several genera and sub-genera by Roubaud, Enderlein and Malloch. Edwards⁵, however, pointed out that the generic and sub-generic characters of these authors broke down when sufficient material was examined, and he divided the British species of *Simulium* into well-defined groups. The Ethiopian species, on the whole, agree with his Group 2; there are, however, certain marked exceptions. *Simulium damnosum*, for instance, though possessing the greatly flattened fore-tarsi (fig. 1) of Group 1, has the fore-tibia covered with coarse silvery pubescence, and not fine silvery dusting. It also differs from those of Group 1 in having the middle section of the radius hairy. Another species showing relationship with Group 1 is *Simulium griseicollis*, which, as was pointed out to me by Mr. Edwards, has the middle section of the radius bare (fig. 2, a), thus differing from all the other Ethiopian species.

Apart from this the Ethiopian SIMULIIDAE do not readily fall into easily defined groups. A character which is very definite, easily recognised, and of which there do not appear to be any intermediate stages, is the presence of a small patch of soft hairs on the pleurae (fig. 3) in three species, namely, *S. gilvipes*, *S. dentulosum* and *S. neireti*. Malloch¹⁴ has used this character for separating off two American species, which further resemble the three Ethiopian species mentioned above in having the basal tooth of the claw, in the female, poorly developed or entirely absent.

Until more material is available it seems more convenient to regard the Ethiopian species as consisting of one group only.

Key to the Females.

- | | | |
|---|-----------------------------|----|
| 1. Fore-tarsi greatly flattened | <i>damnosum</i> , Theo. | |
| Fore-tarsi not at all flattened or only slightly so | ... | 2 |
| 2. Mesothorax with bands of silvery pubescence | <i>imerinae</i> , Roub. | |
| Mesothorax without such bands | ... | 3 |
| 3. Abdomen banded, the fourth tergite being darker than the rest | <i>woodi</i> , sp. n. | |
| Abdomen not banded | ... | 4 |
| 4. A patch of soft hairs present on the pleurae just behind the mesothoracic spiracle (fig. 3) | ... | 5 |
| No such patch present | ... | 7 |
| 5. Mesothorax with three distinct black stripes; integument and pubescence greyish | <i>neireti</i> , Roub. | |
| Mesothorax without any striping; integument very dark, shiny | ... | 6 |
| 6. Thoracic pubescence mostly golden | <i>gilvipes</i> , Pom. | |
| Thoracic pubescence mostly black | <i>dentulosum</i> , Roub. | |
| 7. Claws simple | ... | 8 |
| Claws toothed (<i>i.e.</i> , with thumb-like basal projection) | ... | 14 |
| 8. The patch of hairs at the base of the radius yellowish | ... | 9 |
| This patch dark in colour, usually black | ... | 10 |
| 9. Smaller species; legs with light and dark areas; pubescence mostly silvery | <i>bovis</i> , sp. n. | |
| Larger species; legs mainly dark; pubescence golden | <i>medusaeformis</i> , Pom. | |

- | | | | |
|-----|--|--|----|
| 10. | Front very narrow, thoracic integument somewhat shiny | <i>speculiventre</i> , End. | |
| | Front normal in width ; thorax not shining | ... | 11 |
| 11. | Femora and tibiae all dark | ... | 12 |
| | Femora and tibiae lighter with dark apices | <i>nyasalandicum</i> , sp. n. | |
| 12. | Smaller ; thoracic pubescence less dense ; pubescence of hind tibia nearly all pale... | <i>wellmani</i> , Roub. | |
| | Larger ; thoracic pubescence denser ; pubescence of hind tibia black on apical half ... | | 13 |
| 13. | Hind metatarsus all black | <i>neavei</i> , Roub. | |
| | Hind metatarsus yellowish on basal half | <i>vorax</i> , Pom. | |
| 14. | The patch of hairs at the base of the radius pale ; hind tibia without a sub-basal dark band | ... | 15 |
| | This patch of hairs dark | ... | 16 |
| 15. | Hind metatarsus all black ; pubescence golden | <i>nigritarsis</i> , Coq. | |
| | Hind metatarsus dark only at the apex ; pubescence silvery | <i>griseicollis</i> , Beck. | |
| 16. | Antennae clear yellow | ... | 17 |
| | Antennae dark, with short greyish pubescence | ... | 18 |
| 17. | The light and dark areas of the legs very definite | <i>diversipes</i> , Edw. | |
| | Dark areas not well distinguished from the light | <i>beckeri</i> , Roub. | |
| 18. | Terminal abdominal segments shining, pubescence denser on basal segments | ... | 19 |
| | Terminal abdominal segments not shining, pubescence not concentrated on basal segments, but evenly and finely distributed ; hind tibia without a sub-basal dark band | ... | 22 |
| 19. | Hind tibia with a sub-basal dark band | ... | 21 |
| | Hind tibia with the basal half all yellow | <i>cervicornutum</i> , Pom. | |
| 20. | Frons with bluish or violet iridescence, bare ; pubescence of mesonotum mainly blackish ; integument as seen from above somewhat shining ; abdominal pubescence mainly black | <i>palmeri</i> , Pom. ; <i>blacklocki</i> , Edw., sp. n. | |
| | Frons greyish, not iridescent, but more or less densely covered with golden pubescence ; pubescence of thorax golden, integument quite dull | ... | 21 |
| 21. | Hind tibia with less than the apical half dark, preceded by a broad pale ring ; pubescence on frons and abdomen coarser, denser, and more golden | <i>alcocki</i> , Pom. | |
| | Hind tibia with the apical half dark, preceded by a narrow pale ring ; pubescence on frons and abdomen less dense, that on abdomen partly dark | <i>unicornutum</i> , Pom. | |
| 22. | Smaller ; hind tibia with less than apical half black | <i>hirsutum</i> , Pom. | |
| | Larger ; hind tibia with apical half or more black | <i>aureosimile</i> , Pom. | |

***Simulium bovis*, sp. nov. (figs. 1a, 2b).**

♀. Length, 1.7 mm.

Head: face and frons silvery grey with a pale yellowish pubescence. *Antennae* very dark brown with fine grey pubescence, the two basal joints paler. *Thorax* greyish, with some very distinct black markings. The most distinct of these are three dark bands arranged as follows: one broad median stripe running to the anterior margin of the thorax and on each side of this is a narrower band running parallel to it, but not reaching the anterior margin. The thorax is covered with a pale, almost silvery pubescence. Scutellum with long yellow hairs. *Pleurae*

without the patch of soft hairs on the membrane behind the mesothoracic spiracle. *Halteres*: crown pale yellow, stalk dusky. *Wings* hyaline, radius unforked, patch of hair at the base of the radius yellowish. *Legs*: front legs with coxae yellow; femora yellow; tibiae with basal two-thirds yellow, apical third dark brown; tarsi very dark, almost black. Mid legs with coxae, femora and basal two-thirds of tibiae yellow, rest of the tibiae, and all the tarsi very dark, almost black. Hind legs with coxae yellow, femora and tibiae yellowish, or light brown, on the basal half, darker brown on the apical half; first hind tarsal with almost black apex and base, sharply defined from the middle portion, which is very pale yellow; basal third of the second hind tarsal pale, apical third and rest of the tarsi very dark, almost black. Coxae, and pale regions of all legs, with yellowish pubescence. *Abdomen*: first abdominal tergite with long pale hairs, rest of the abdomen covered fairly densely with a coarse silvery pubescence (pale yellow in some parts).

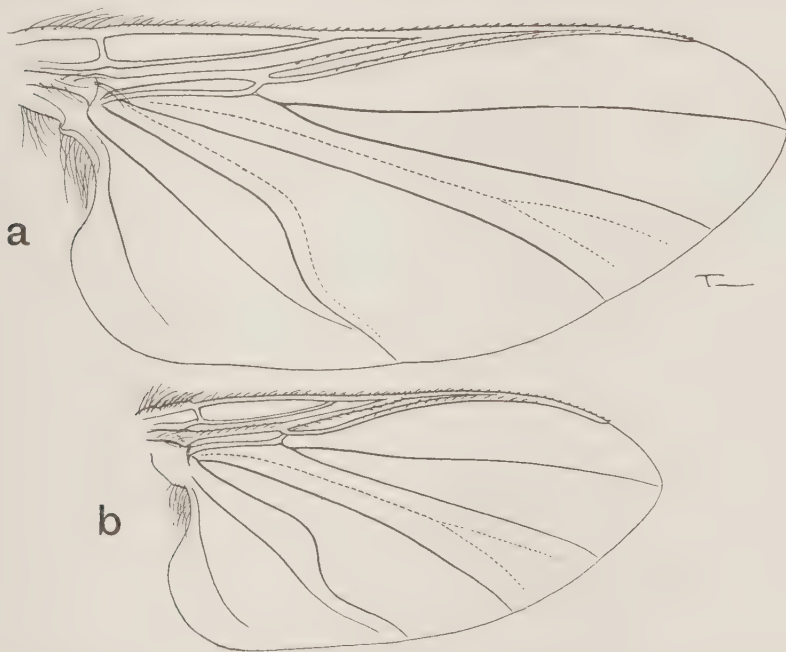


Fig. 2. Wings of, *a*, *Simulium griseicolle*, Becker, and *b*, *S. bovis*, sp. n., to show hairs on base of radius in the latter.

ZULULAND: Umhlatuzi, 4.iv.23 (G. A. H. Bedford—type). NYASALAND: numerous specimens (R. C. Wood).

It is an interesting fact that the specimens from Nyasaland and Zululand are all recorded as having been taken on cattle. In general appearance this insect greatly resembles *griseicolle*, from which it differs in having the claws simple. It is easily distinguished from *wellmani* by its yellow femora and tibiae, and from *medusaeformis* by its silvery, instead of golden pubescence.

***Simulium blacklocki*, Edwards, sp. n. (fig. 4, f).**

Adult. Closely resembles *S. palmeri*, Pom., both externally and in the structure of the male genitalia. No obvious distinctions can be discovered in the material

available, but all the females have the thorax somewhat rubbed; some golden scaly hairs remain on the dorsum, and it may be that these are more numerous, in proportion to the dark hairs, than in *S. palmeri*.

Pupa. Respiratory organ totally different from that of *S. palmeri*, or, indeed, from any other species of *Simulium* hitherto known. Basal portion consisting of a large sac (collapsed in all the specimens at hand, but probably filled out in life); inner wall of sac (adjacent to front of thorax) formed of perfectly smooth chitin, outer wall with a conspicuous honeycombed structure, as in the whole organ of *S. palmeri*. From the outer or front wall of the sac, towards its anterior edge, project two stout finger-like processes, in which the hexagonal structure of the chitin is scarcely distinguishable.

SIERRA LEONE: Type ♂ pupa, with ♂ hypopygium dissected therefrom; several empty pupae, and 2 ♂♂, 5 ♀♀, reared from pupae; all collected by Prof. B. Blacklock in 1926 and presented by him to the British Museum.

***Simulium woodi*, sp. nov.**

♀. *Length*, 2.5 mm.

Head: face and frons grey, covered with coarse golden pubescence. *Antennae* dark brown with fine grey pubescence, the two basal segments paler. *Thorax* uniformly clothed with golden pubescence, a shade paler laterally. Scutellum with long yellowish hairs. Pleurae without a patch of soft hairs on the membrane behind the mesothoracic spiracle. *Halteres*: lemon-yellow with darker stalks. *Wings* hyaline, radius unforked. *Legs*: front legs with coxae dark brown, with golden pubescence; tibiae, basal half yellow, apical half with dark reddish pubescence; tarsi very dark brown. Mid legs with coxae dark brown with yellow pubescence; femora as in front legs, dark brown with scattered yellow pubescence basally; tibiae, basal half paler, with yellow, and apical half with dark reddish pubescence; first tarsal segment almost black, with scattered yellow pubescence basally, rest of the tarsal joints very dark, almost black. Hind legs with coxae dark brown, with yellow pubescence; femora very dark brown with scattered yellow pubescence basally; tibiae, basal half paler, with yellow, and apical half with dark reddish pubescence; first tarsal joint with basal half yellow except for a dark brown line down the front edge, basal half and rest of the tarsal joints almost black. Second hind tarsal joint with an excision near the base. Claws with a small basal tooth. *Abdomen* covered with dense, rather coarse pubescence, which is mainly golden or yellowish on all segments except the dorsal part of the fourth segment, which is clothed with a dark reddish pubescence; there is also some reddish pubescence mixed with the yellow on the apical segments.

NYASALAND: Cholo, 4 ♀♀, 14.ix.1917 (*R. C. Wood*).

This insect is easily distinguishable from all other Ethiopian species by the conspicuous dark band on the otherwise golden abdomen.

***Simulium nyasalandicum*, sp. nov.**

There are five females in the British Museum collection, and one specimen is labelled "type" Roubaud. It appears, however, that it was never described. It is very closely allied to *S. neavei* and their separation is a difficult matter. Unfortunately neither the males nor early stages of either species are known.

A description of the female, based on the examination of five specimens, is given below.

♀. *Length*, 2.4 mm.

Head: face and frons grey, with golden pubescence. *Antennae* dark, with fine, greyish pubescence, the two basal segments slightly paler. *Thorax* velvety-black,

covered with dense golden pubescence, also some darker, reddish and more scattered pubescence. Pleurae lacking the patch of soft hairs on the membrane behind the mesothoracic spiracle. *Wings* hyaline, radius unforked; the patch of hairs at the base of the radius dark. *Halteres*: crown pale, waxy in appearance, stalks dusky. *Legs*: coxae of all legs dark brown with coarse golden pubescence. Fore femora and tibiae with golden pubescence on basal half, apical half dark; tarsi all dark, almost black. Hind legs with scattered golden pubescence on femora, tibiae with basal half yellowish, rest dark; first tarsal segment a shade paler basally, rest of the tarsi dark, almost black. Claws simple. *Abdomen* uniformly covered with dense golden, and scattered dark red, pubescence.

NYASALAND: Mt. Mlanje (S. A. Neave).

Simulium nigratarsis, Coq.

Simulium nigratarsis, Coquillett, Proc. U.S. Nat. Hist. Mus., xxiv, 1901, p. 27.

Coquillett made his description from six females from the Cape Colony; it is very brief, and since he did not describe the male, it is rather difficult to know what *nigratarsis* really is. There are none of Coquillett's original specimens in the British Museum collection; there are, however, specimens from Nyasaland, Natal, and the Transvaal, which appear to agree with his description very well. Other specimens from Nyasaland, collected at a later date by Mr. R. C. Wood, although agreeing fairly well with Coquillett's description, yet differ in many respects from the series mentioned above. The genitalia of the males, associated with both series of specimens, show no appreciable difference, so that in spite of the apparent difference they are not here regarded as a new species.

A re-description of *nigratarsis*, female, with the extent of the variations is given below, and the male is here described for the first time.

♂. *Antennae* vary from black to pale yellow, much resembling those of *beckeri*. In specimens with dark antennae, the basal two segments are paler, while in some specimens with pale antennae the segments are faintly ringed with darker narrow bands. *Thorax*: integument very dark, velvety-black in some specimens. The vestiture of the scutum varies greatly, in some the pubescence is nearly all black with lighter golden patches laterally and on the scutellum, in others the whole of the scutum is clothed with a golden pubescence interrupted by a broad, median, longitudinal stripe of reddish brown pubescence. This latter condition, which can often be seen with the naked eye, is especially marked in the specimens sent by Mr. R. C. Wood from Nyasaland. *Wings*, in all specimens from Nyasaland, with the patch of hairs at the base of the radius yellow, but males from Weenen, Natal, have this patch black. So far this is the only case in which the colour of this patch of hair has been seen to vary within the same species. Radius normal. *Legs*: front legs with coxae and femora yellow, the femora may be darkened towards the apex; tibiae with the apical quarter or third dark, rest yellowish; tarsi black. Hind legs with coxae yellow or light brown; femora with basal quarter, varying to a half, yellow, the rest dark brown; tibiae with basal half yellow, rest of the tibiae and the tarsi all black. The yellow portions of the legs are covered with golden pubescence; the pale portions vary from clear to dirty yellow. *Abdomen* covered with a golden pubescence on all segments. *Genitalia*: side-pieces longer than the claspers, latter only very slightly, if at all, expanded apically; apex with one terminal tooth. The adminiculum bilobed apically, the lobes being somewhat conical in shape. The genitalia resemble very closely those of *bracteatum*, Coq., and *angustatarsis*, Lundst., its American and European representatives. Two other species that have a very similar type of genitalia are *diversipes*, Edw., and *beckeri*, Roub.; in these, however, the lobes of the adminiculum are not so pointed, and the claspers are more expanded apically.

♀. *Head*: frons and face covered with a golden pubescence. *Antennae* varying as in the male. *Thorax* with dense golden or yellow pubescence. In some specimens the colour is uniform, in others there are two broad stripes of dark reddish brown pubescence in the middle of the scutum; this latter condition, as in the males, is especially prominent in specimens collected by Mr. R. C. Wood in Nyasaland. Scutellum with long yellowish hairs. *Legs* all black, except the coxae, front femora, most of the mid femora, basal two-thirds or half of the hind femora, three-quarters of the front tibiae and basal half of the hind and mid tibiae. In the females the pale and dark areas are much more sharply defined than in the males. Second hind tarsal joint with a dorsal excision. Claws with a well developed basal thumb. *Wings* with radius normal; the patch of hairs at the base of the radius is pale in all specimens, irrespective of locality. *Abdomen*: first abdominal tergite with long yellowish hairs, rest of abdomen covered with a dense, rather coarse, golden pubescence, silvery in some places, especially laterally.

NYASALAND: (R. C. Wood). SOUTH AFRICA: Weenen, Natal (H. P. Thomasset); Drakensberg, Natal (R. E. Turner); Pretoria, Transvaal (G. A. H. Bedford); Cape Colony.

Some of Wood's specimens are labelled as having been taken "on orange," others as occurring in the rump feathers of a *Francolinus*.

Simulium diversipes, Edw.

Simulium diversipes, Edwards, Ann. & Mag. Nat. Hist. (9) xii, 1922, p. 333.

Male, female and pupa described.

This species is very closely allied to *beckeri*, Roub. The present series of specimens are separable as shown in the key. The male genitalia of the two species appear to be inseparable, furthermore, *diversipes*, although originally described from Rodriguez, has since been found in Java, Sierra Leone and Natal. It is not improbable, therefore, that more material will show the two species to be conspecific.

RODRIGUEZ. SOUTH AFRICA: Weenen, Natal (H. P. Thomasset). WEST AFRICA: Freetown, Sierra Leone (Dr. Blacklock). JAVA (H. M. Pendlebury).

Simulium beckeri, Roub. (figs. 4g, 6b).

Simulium beckeri, Roubaud, Bull. Mus. Paris, xii, 1906, p. 520.

Male and female described.

Edwards² has already pointed out that *S. divergens*, Pom., is a synonym of this species.

ALGERIA: Biskra.

Simulium gilvipes, Pom. (figs. 3, 4j and 5a).

Simulium gilvipes, Pomeroy, Ann. & Mag. Nat. Hist. (9) vi, 1920, p. 75.

Male, female and pupa described.

In addition to Pomeroy's specimens there are in the British Museum five females collected by Capt. A. D. Fraser in Uganda. These, though agreeing in the main with *gilvipes*, appear to differ in the uniformly darker legs, and in having the pubescence on the apical abdominal segments paler than on the more basal ones.

CAMEROONS (Pomeroy); UGANDA: (Capt. A. D. Fraser); NYASALAND: Dowa (R. C. Wood).

Pupae found in quick-flowing mountain streams. Adults not found biting.

Simulium dentulosum, Roub.

Simulium dentulosum, Roubaud, Bull. Soc. ent. France, 1915, p. 294.

Female only described.

UGANDA: (*S. A. Neave*); KENYA COLONY: (*S. A. Neave*).

Simulium neireti, Roub. (fig. 1, *d*).

Simulium neireti, Roubaud, Bull. Mus. Paris, xi, 1905, p. 425.

Female only described.

This and the two preceding species are the only known Ethiopian SIMULIIDAE which have a patch of soft hairs on the membrane immediately behind the mesothoracic spiracle. They further resemble one another in having the tarsal claws with a small tooth; in the case of *neireti* the tooth is almost non-existent. *S. neireti* further differs from the other two and from all the other species in the development of the fourth tarsal segment, which is as long as or even longer than the fifth.

MADAGASCAR (*J. J. Lloyd, E. Roubaud, W. C. Holden*).



Fig. 3. *Simulium gilvipes*, Pom., showing the small patch of soft hairs (X).

Simulium neavei, Roub.

Simulium neavei, Roubaud, Bull. Soc. ent. France, 1915, p. 293.

Female only described.

UGANDA (*S. A. Neave*); KENYA COLONY (*F. W. Dry*); Kakumega Forest (*S. A. Neave*).

This species is suspected of being the carrier of a disease among natives of the Lumbwa tribe in Kenya according to *F. W. Dry*,⁴ who writes as follows:—

"The flies are active, the Lumbwa told me, and my own observations are consistent with what they said, from about seven o'clock in the morning until five in the afternoon, and especially so in the afternoon. Very little is seen of them when rain is falling, and I was told, and from my own collecting believe it to be so, that the

flies are not so active in intense sunshine as when the sun is less bright. They pay little attention to people on the march, but if one remains still in infested country they appear immediately. They bite very readily and often raise half-inch wheals, a drop of blood frequently exuding from the puncture It is the accepted belief of the Lumbwa and Kisii amongst whom I moved, that a disease is caused by the bite of these flies, the chief symptom being that the skin is in folds. It would seem that these folds appear first on the small of the back, but sometimes the skin higher up the back, and more rarely that of the front and sides of the body, was seen to be affected in the same way, while occasionally, though this was only so with elderly people, the condition would extend to the arms and legs. Sometimes the skin was spotty, and occasional cases were shown to me as *Simulium* disease in which spots, but no folding, were present. People with the affection scratch themselves a great deal. Many of the affected people that I saw were able to carry on their usual activities, but some looked to be in quite a feeble condition."

***Simulium vorax*, Pom.**

Simulium vorax, Pomeroy, Bull. Ent. Res., xii, 1921. p. 461.

Female only described.

This species is very closely allied to *S. neavei*.

Pomeroy took the females biting voraciously and engorging on a donkey near a stream.

TANGANYIKA TERRITORY: Amani (*A. W. J. Pomeroy*).

***Simulium griseicolle*, Becker (figs. 1c, 2a).**

Simulium griseicolle, Becker, Mitt. zool. Mus. Berlin, ii, 3 Heft, pp. 78-79;

"Austen. Second Report Wellc. Res. Labs. Khartoum, p. 52 (1906).

Austen, in the paper noted above, has given a translation of Becker's original description as well as some interesting notes on the habits of this vicious biter.

King¹² has given a superficial description of the larva and pupa. According to him each filament of the pupa is composed of three, broad leaf-like branches; this should easily distinguish it from other pupae. He found the larvae and pupae in the swiftest running streams.

The adult differs from all other species of Ethiopian SIMULIDAE in having the middle section of the radius bare.

ANGLO-EGYPTIAN SUDAN (*H. H. King*); NORTHERN NIGERIA (*J. McF. Pollard*); SIERRA LEONE (*E. Hargreaves*).

Austen (African Blood Sucking Flies, 1909, pp. 31-32) quotes a letter from the Mudir of Berber to Dr. A. Balfour in 1905 as follows:—

"It occurs in January, February, March and April. It extends from Salamanieh, north of Berya, to the Besti boundary of the Dongola Province on the river. It lives near the river and is not found at a greater distance from it than half a mile. It bites from sunrise to sunset, attacking any part of man or beast unprotected by hair or clothes. Human beings are chiefly bitten on the face and hands. It is most virulent between the extreme cold of the winter and the great heat of the summer. The hot weather kills these flies off in thousands, and finally extinguishes them. On very cold days they are not aggressive."

***Simulium medusaeformis*, Pom. (figs. 4k, 5c).**

Simulium medusaeformis, Pomeroy, Ann. & Mag. Nat. Hist. (9) vi, 1920, p. 76.

Male, female and pupa described. The pupa is remarkable in having secondary filaments arising from four main stems.

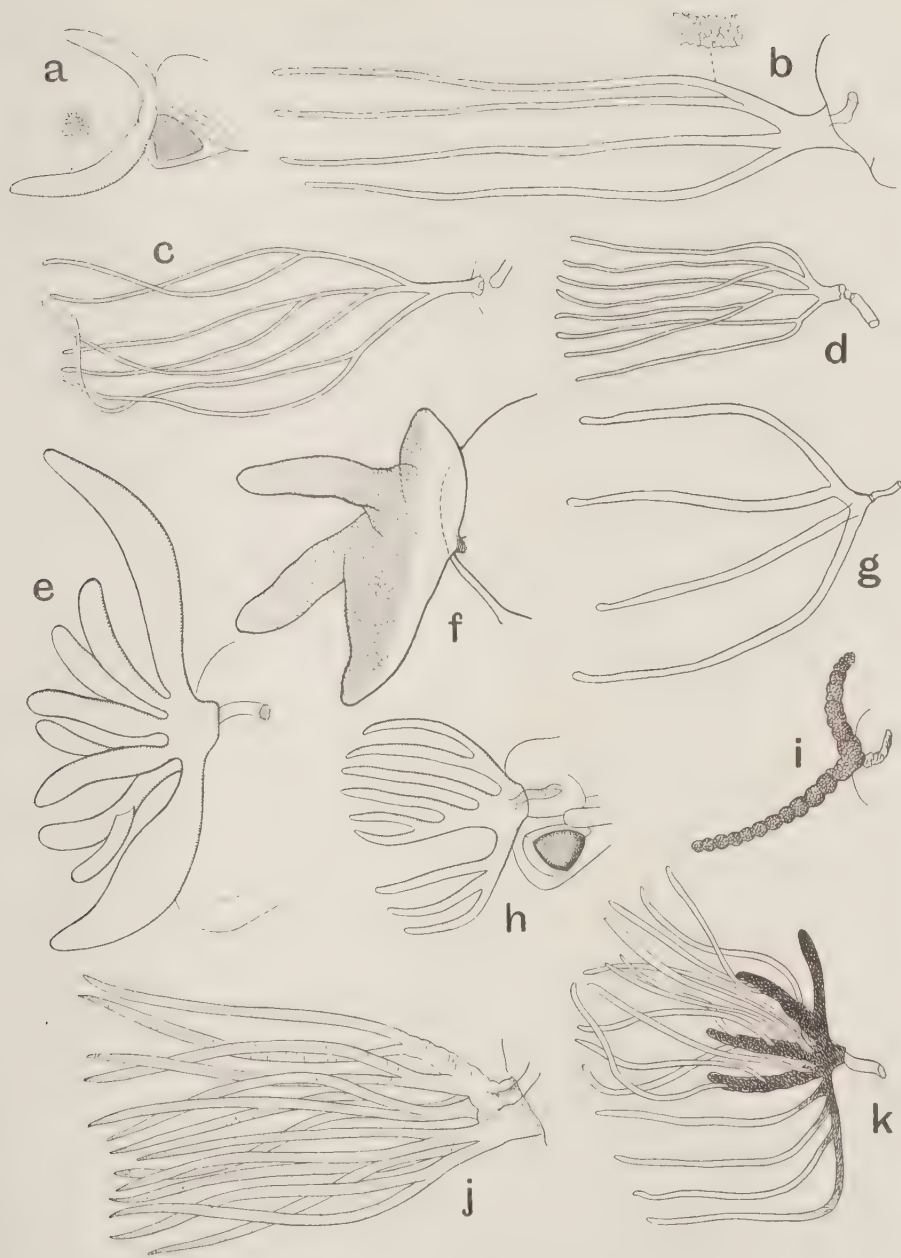


Fig. 4. Pupal respiratory filaments of : a, *Simulium unicornutum*, Pom.; b, *S. aureo-simile*, Pom.; c, *S. alcocki*, Pom.; d, *S. hirsutum*, Pom.; e, *S. damnosum*, Theo.; f, *S. blacklocki*, Edw., sp. n.; g, *S. beckeri*, Roub.; h, *S. cervicornutum*, Pom.; i, *S. palmeri*, Pom.; j, *S. gilvipes*, Pom.; k, *S. medusaeformis*, Pom. (After Pomeroy.)

CAMEROONS : (Pomeroy) ; CONGO FREE STATE (*A. Yale Massey*) ; SIERRA LEONE (*Dr. Blacklock*) ; KENYA (*G. B. Purvis*) ; SOUTH AFRICA : Capetown (*H/K Barnard*).

The pupae have been found in quick-flowing mountain streams. The adults have not been observed to bite.

***Simulium wellmanni*, Roub.**

Simulium wellmanni, Roubaud, Bull. Mus. Paris, xii, 1906, p. 519.

The female only is known. A small very dark species with greyish pubescence on the otherwise dark legs. The scutum of the thorax is mainly black ; there is, however, some greyish pubescence laterally.

ANGOLA (*F. C. Wellman*) ; BELGIAN CONGO : Katanga (*J. Schwetz*) ; CAPE COLONY : Worcester (*R. E. Turner*).

Austen in his book on African Blood Sucking Flies (p. 30) quotes Dr. F. C. Wellman's field note on this species as follows : " Native name *ohomono*. These tiny flies bite viciously and are dreaded by native porters. Their bite leaves a large weal, with a small red spot in the centre, and itches for several days."

***Simulium speculiventre*, End.**

Simulium speculiventre, Enderlein, Trans. Linn. Soc. Lond., xvi, 1914, p. 374.

Male and female described.

This species is easily recognised, by the very narrow front, from all other females of Ethiopian *Simulium*.

SEYCHELLES.

***Simulium palmeri*, Pom. (fig. 4, i).**

Simulium palmeri, Pomeroy, Bull. Ent. Res., xii, 1922, p. 462.

Male, female and pupa described.

NIGERIA (*Pomeroy*).

Pupae in quick-flowing hill stream. Adults not found biting.

***Simulium cervicornutum*, Pom. (figs. 4h, 5e).**

Simulium cervicornutum, Pomeroy, Ann. & Mag. Nat. Hist. (9) vi, 1920, p. 73.

Male, female and pupa described.

CAMEROONS (*Pomeroy*).

Pupae in quick-flowing mountain streams. Adults not found biting.

***Simulium unicornutum*, Pom. (figs. 4a, 6a).**

Simulium unicornutum, Pomeroy, Bull. Ent. Res., xii, 1922, p. 462.

This species was originally described from the pupa,¹⁷ which was distinct from that of all other known Ethiopian species, though somewhat resembling that of *palmeri*. The adult is easily separable from *palmeri*, but resembles *alcocki* very closely.

NIGERIA (*Pomeroy*) ; SIERRA LEONE (*Dr. Blacklock*).

Pupae on blades of grass in a small stream. Adults not found biting.

Simulium imerinae, Roub.

Simulium imerinae, Roubaud, Bull. Mus. Paris, xi, 1906, p. 426.

Female only described. There are no specimens of this species in the British Museum, but according to Roubaud's description, it should be very easily recognised by the white stripes on the thorax.

MADAGASCAR.

Simulium hirsutum, Pom. (figs. 4d, 6d).

Simulium hirsutum, Pomeroy, Bull. Ent. Res., xii, 1921, p. 458.

Male, female and pupa described. Pomeroy also describes, in the same paper two pupal varieties var. *dubium* and var. *adersi*.* The adults bred from these pupae do not differ from the type. Edwards⁸ has recorded the occurrence of the larvae and pupae on a fresh-water crab, *Potamon niloticum*, from a river in Uganda.

TANGANYIKA TERRITORY (*Pomeroy*); UGANDA: Lake Victoria (*G. D. Hale Carpenter*); SIERRA LEONE (*Blacklock*).

Pupae found attached to grass-blades in a swift stream. Adults not found biting.

Simulium aureosimile, Pom. (figs. 4b, 6c).

Simulium aureosimile, Pomeroy, Ann. & Mag. Nat. Hist. (9) vi, 1920, p. 78.

Male, female and pupa described.

CAMEROONS (*Pomeroy*).

Larvae and pupae in a slow-moving stream. Adults not found biting.

Simulium alcocki, Pom. (figs. 4c, 5d).

Simulium alcocki, Pomeroy, Bull. Ent. Res., xii, 1922, p. 459.

Male, female and pupa described. Pomeroy also describes two varieties, var. *violaceum* and var. *coalitum*, founded on the branching of the pupal filaments. The adults from these pupae are said not to differ appreciably from the type.

NYASALAND (*R. C. Wood*); NIGERIA: Ibadan (*Pomeroy*); SIERRA LEONE (*Blacklock*).

Pupa found attached to grass-blades in a slow-moving stream. Adults not found biting.

Simulium damnosum, Theo. (figs. 1c, 4e, 5b).

Simulium damnosum, Theobald, Rept. Sleeping Sickness Comm., iii, 1903, p. 40.

This species can be very readily recognised by the greatly flattened front tarsi and the silvery pubescence of the front tibiae. The male and pupa, described by Pomeroy,¹⁷ are also very distinct. It is a very widely distributed species, and further search will probably reveal its presence in many more localities.

LIBERIA (*Major A. Pearce*); GOLD COAST (*J. J. Simpson*); CAMEROONS (*Pomeroy*); BELGIAN CONGO (*Christy*); UGANDA (*Christy*); ANGLO-EGYPTIAN SUDAN (*Col. Talbot*); TANGANYIKA TERRITORY: Amani (*Pomeroy*); NYASALAND (*R. C. Wood*); SOUTH AFRICA: Pretoria, Transvaal (*G. A. H. Bedford*); Weenen, Natal (*Thomasset*).

* Pupae agreeing with *S. hirsutum* var. *adersi*, Pom., were collected by Mr. W. N. Edwards at a spot about 15 miles south of Rejaf, Southern Sudan, in August 1929. The pupa of this form is so different from that of typical *S. hirsutum* that it seems very probable that it will eventually be found to be a distinct species.—F. W. EDWARDS.

Dr. Blacklock,³ working in Sierra Leone, has shown this species to be the vector of a Nematode, *Onchocerca volvulus*, L., which in the embryo stage is sometimes found in the skins of 45 per cent. of the inhabitants. He was able to infect 82 per cent. of the flies feeding on heavily infected cases, and wild flies showed a natural infection of 2.6 per cent.

Pomeroy found the pupae attached to rocks in a swift-flowing stream.

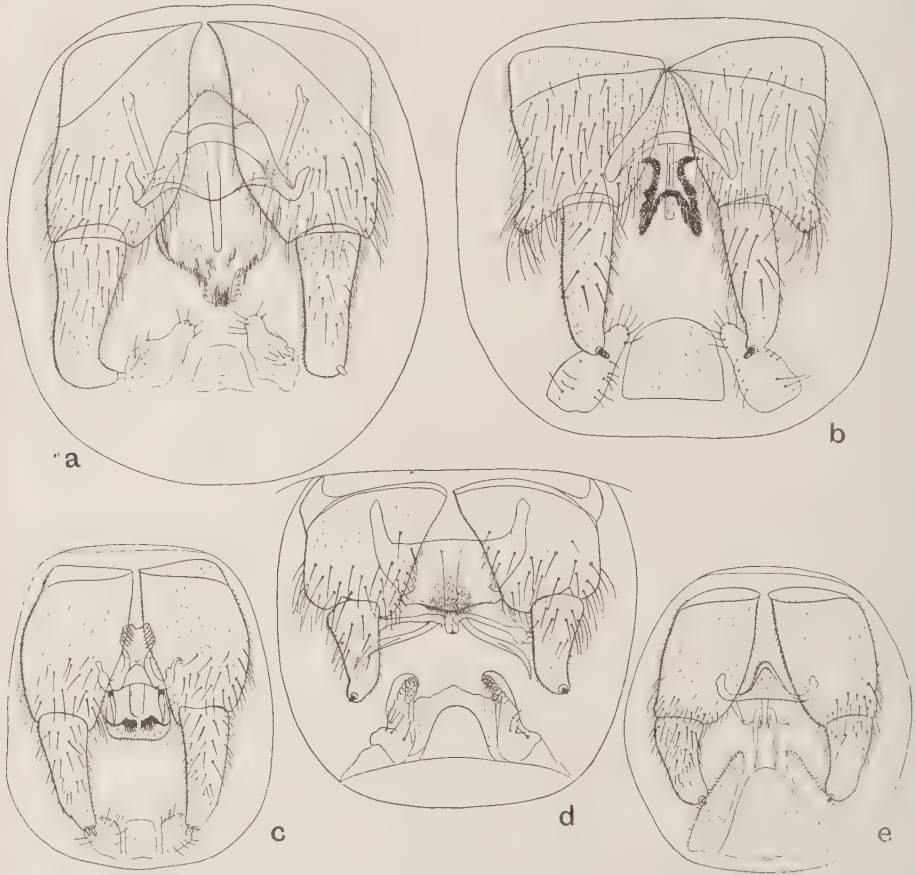


Fig. 5. Male genitalia of : a, *Simulium gilvipes*, Pom. ; b, *S. damnosum*, Theo. ; c, *S. medusaeformis*, Pom. ; d, *S. alcocki*, Pom. ; e, *S. cervicornutum*, Pom. (After Pomeroy.)

The females are known as very vicious and persistent biters of human beings and animals. Austen, in his "African Blood Sucking Flies" (p. 28), quotes Mr. M. T. Dawe, who says of this species : " This small biting fly is known to the natives as *mbwa*. Its bite is very poisonous and irritable and causes large swellings, which usually end in sores. Localities where it is present are very sparsely inhabited." Austen also quotes further evidence of the voracity of this fly.

H. Hargreaves¹¹ has given some account of the bionomics of this species in Uganda, recording the fact that, in addition to man, it also feeds on game and birds, and that it is most prevalent during January, the driest month. He comes to the conclusion that they fly great distances in search of food, and that they are most active on bright sunny days. Eggs are found only on rocks and aquatic plants in rapids, none in smoother water.

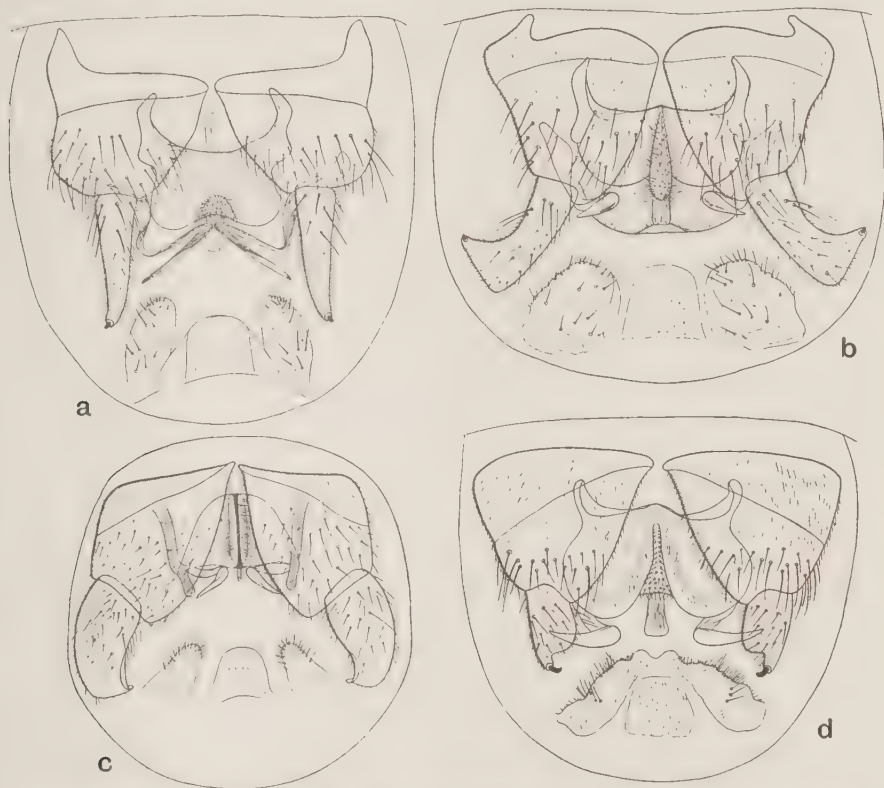


Fig. 6. Male genitalia of: a, *Simulium unicornutum*, Pom.; b, *S. beckeri*, Roub.; c, *S. aureosimile*, Pom.; d, *S. hirsutum*, Pom. (After Pomeroy.)

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A CONTRIBUTION TO OUR KNOWLEDGE OF THE BIONOMICS OF *GLOSSINA MORSITANS*.

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(Map.)

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1. GENERAL INTRODUCTION.

The writer is in charge of the Kikori Entomological Station, the staff consisting of an Entomologist and an Observer. The Entomologist commenced work in this area in March 1928, being joined in December 1928 by Captain V. A. C. Findlay, the Observer. Since that time an Ecological Station has been established under the direction of Dr. J. F. V. Phillips.

The native village of Kikori is situated at the foot of the Masai escarpment, which bounds the Masai Steppe on the west. Kikori lies about 45 miles north of Kondoa-Irangi (the principal centre of the district), its approximate bearings being Latitude 4° 21' S. and Longitude 35° 19' E.; its elevation is 4,158 feet above sea-level.

This village is situated in the densest part of the Kondoa Eastern Tsetse-fly belt, which is represented by a linear strip of country running along the foot of the escarpment and having an average width of approximately seven miles. On the east it is bounded by the edge of the Masai Steppe, which here is represented by a grassy plain known as the "Great Mbuga"; owing to the scarcity of fly above 5,000 feet, the western limit is formed by the escarpment. On the eastern edge *Glossina morsitans* merges into *G. swynnertoni*, which species is thinly distributed over the N.W. portion of the Masai Steppe.

Kikori is particularly well situated as a research station for investigating the bio-ecology of *G. morsitans* for the following reasons: The fly density is very high, and hence an unlimited amount of material is available for observational and

experimental purposes. The bush is laid out in almost diagrammatic order from the rain forest covering parts of the top of the escarpment, down to the open grassy plains of the Masai Steppe. Hence in a very small area fly can be studied in a large number of vegetational habitats—habitats which are representative of a very considerable portion of the territory. Many species of big game are represented in this district, ranging from the Greater Kudu that frequents the hills, down to the Brindled Gnu and gazelles of the Steppe.

Thus, in the neighbourhood of Kikori, one has dense fly showing preferences for certain of the many available types of vegetational habitat, and for certain of the many available species of game. On account of this, it has been one of the purposes of the investigation to try to correlate the varying density of fly with the changes noted in the environmental factors—season, vegetation and food supply.

The three following methods have been employed in studying the bionomics of *G. morsitans*:—Fly-rounds; breeding of tsetse in an insectary; and experiments with marked flies.

Dr. Phillips has extracted the following information, describing the history of the fly belt, from German literature and Government files:—

It appears from a report in the German Government files, by Dr. Schellhayer, the Imperial Veterinary Officer of Kondoa-Irangi, that Kikori was originally free from fly. He gives a rough sketch-map of the fly distribution, from which it is clear that the original tsetse concentrations were at Kandaga and the Kissesse point (*see* Map). On 8th August 1909 he found that the fly had spread northwards to Kikori, and southwards to Itundwe. Cattle had to be removed from both villages.

When Dr. E. Obst visited Kikori on 1st December 1911 he describes the village as being severely infested by tsetse.

The writer is indebted to Dr. Phillips for the following information with regard to the important physical features of the fly belt.

The Main Soil Types.

Red alluvial soils have been deposited along the foot of the escarpment. They range between sand and heavy clay, and their depth may exceed 60 to 150 feet. They vary in quality from good to poor.

Grey alluvial soils vary from light sandy loams to heavy clays, such as the so-called "mbuga" or "black cotton" soil. This soil is represented in the Masai Steppe and is found in the small "mbugas" that occur within the fly belt.

Grey alluvial sands and sandy loams are represented upon the hills forming the escarpment; they overlie the decomposing gneiss, and are less than 18 inches in depth.

The forest soils occur in the highest portions of the escarpment, where there is evergreen sub-tropical forest. Since *G. morsitans* does not occur at these altitudes they need not be discussed.

Climate.

The climate may be divided into two dry and two wet seasons. The long dry season commences shortly after the end of the heavy rains, in late April or early May. This dry season is characterised by a cold spell which normally takes place in July, followed by a rise in temperature, until the light or short rains break in late October or early November. These light rains last until the beginning or end of January, when the second or short dry season commences. This dry season is characterised by a high temperature and low humidity. In late February or early March the heavy or long rains break; these last until late April or early May. There appears to be a considerable variation in the date of arrival of these seasons.

The Long Dry Season.—This, the true dry season, during which there are only a few millimetres of rainfall, is characterised at Kikori by the following features :—

For a considerable period after the heavy rains have ended, the sky remains over-cast until mid-day or later. There may be a very fine drizzle until 10 a.m. The night temperature gradually drops, until in July it reaches a minimum. The following extremes were obtained in July 1929 at the Ecological Station :—

Grass minimum 33·25° F.
Minimum thermometer in Stevenson screen ... 38·25° F.

The temperature then rises slowly, and the number of hours of sunshine increases. The deciduous vegetation becomes leafless, and the grasses are tinder-dry ; a period of bush fires ensues.

TABLE I.

Station	Elevation in feet	No. of months observation		Rainfall in inches, by months.												Average
		German	British	1	2	3	4	5	6	7	8	9	10	11	12	
Ufume...	4,495	51	0	4·96	3·39	6·57	6·22	1·50	0·04	0·20	0·20	0·08	0·08	3·27	2·64	29·15
Kikori ...	4,158	0	12	1·70	0·50	5·38	5·90	0·65	0·03	0·05	0·11	0·22	2·25	0·47	3·76	21·02

TABLE II.

Station	Elevation in feet	No. of months observation		Temperature in Fahrenheit, by months												Average
				1	2	3	4	5	6	7	8	9	10	11	12	
Ufume...	4,495	49	Max.	79·70	80·42	79·88	75·02	73·76	71·78	71·06	71·06	74·48	78·44	79·34	80·06	76·28
			Min.	61·16	61·70	62·96	61·70	59·70	55·40	54·50	56·12	57·56	59·54	61·88	62·60	59·54
Kikori ...	4,158	3	Max.						77·20	75·60	79·27					
			Min.						56·90	55·79	55·23					

The Light Rains.—At the commencement of the season, the vegetation bursts into new leaf ; the grasses become green, and the natives cultivate. The temperature continues to rise. The rainfall varies considerably from year to year.

The Short Dry Season.—The fact that this is a dry period is masked by the rainfall statistics, which are comparatively high owing to the severity of an occasional thunderstorm. In some years the grass will become so dry that there will be a recurrence of bush fires and many shrubs appear to wilt. In February 1929 a shade temperature of 105° F. was recorded at 1 p.m., and the humidity was as low as 12 per cent.

The Heavy Rains.—In this season the rainfall is more regularly distributed ; the ground becomes sodden in the mbugas, and grasses may attain a height of 5 to 7 feet.

Some rainfall figures are given (Table I) ; these were taken in German times by the Ufume Mission, which is about five miles north of Kikori. The Mission lies at the foot of Ufume Mountain, the height of which is 7,916 feet, whereas Kikori lies

at the foot of the escarpment at a point where its maximum height is 5,700 feet only, hence these statistics probably are somewhat higher than those that would have been obtained at Kikori.

The figures obtained at Kikori Entomological Station for 1928 to 1929 are also given; these probably are much lower than the average, because the local crops failed for the year, owing to lack of rain.

Rainfall measurements for 1929, taken by the Department of Tsetse Research at Kandaga and Itundwe (two villages also lying at the foot of the escarpment), tend to show that the rainfall decreases as one leaves the foot of the escarpment for the "Great Mbuga."

Shade maximum and shade minimum temperatures have been taken from the Ufume records (Table II). Dr. Phillips considers that, from measurements he has made in the field, these figures do not give a true impression of the temperature conditions experienced by the vegetation communities. In addition a few figures obtained at Kikori Entomological Station are given.

Wind.—From May to October the south-east trades are the prevailing winds; they contain little or no moisture. N.E. winds are also frequent. From late October to May the winds are local, and their general directions are N.E. or S.E. The winds are of velocity 2–5 (Beaufort scale) during the dry season, and 2–4 during the rainy season. Kikori, owing to its vicinity to the escarpment, is from time to time subjected to hot dry winds warmed by compression upon passing from higher to lower levels.

II. FLY-ROUNDS.

INTRODUCTION AND DISCUSSION ON TECHNIQUE.

A fly-round is a survey of tsetse-fly over a fixed route repeated at definite short intervals throughout the year. This method of investigation of a fly population was initiated by Mr. W. H. Potts, Senior Entomologist, Tsetse Research Department, at Selia in November 1927. It has been developed by the writer along the lines described herein.

Fly-rounds have been set out so as to tap the main vegetation types of the district. They enable the observer to keep his finger upon the pulse of the fly community being studied. They yield information as to the seasonal variations in density and breeding activities; the seasonal distribution of fly in different types of bush; the effects upon fly of game movements and grass fires; as well as upon many incidental points likely to be of value.

Should it be desired to make a continued study and fly-survey of a certain tract of bush, the following method is employed:—

The area in question is thoroughly reconnoitred, with a view to ascertaining the distribution of the prevailing vegetational belts. It is desired to discover wooding in which the vegetation types to be studied are of homogeneous composition and clearly demarcated by well-defined boundaries; vegetation communities with ill-defined boundaries or indefinite transition stages are to be avoided.

A route is now planned so as to traverse the different types of wooding, and is sub-divided into sections by numbered trees, which mark the limits of each type of bush. Such a route is referred to as a fly-round and its sub-divisions are referred to as sections. Two such rounds have been instituted at Kikori, and are known, from their respective bearings with the camp, as the N.E. and S.E. Kikori fly-rounds. There is also a fly-round at Kandaga, which is a village 20 miles south of Kikori, also lying at the foot of the escarpment. It serves as a control to the Kikori rounds.

It has been found that six readings for each round can usually be obtained in five weeks. These are carried out at three different periods, at about ten day intervals. It is not considered advisable to catch more often than this lest the numbers of the fly removed should seriously affect the normal density of the area. The two readings for the same period are purposely separated by the interval of a day, lest the displacement caused along the route by the catching should not be rectified on the following day by the inflow of fresh fly.

On one of the two days in a period, the round is done in the reverse direction, so as to insure against the catchers passing the same section at the same time of day. Thus, in each period one has a morning and an evening reading for each of the extreme sections, and by varying the time of starting, or the place selected for the mid-day rest the middle sections also get a fair range in the time of day at which they are visited.

As it is of great interest to be able to compare for the same day the results obtained on one round with those on the other, it is necessary that one should be undertaken by fly boys unsupervised by a European officer. Regrettable though this is, it is considered that, by the adoption of the following methods, the results can be made trustworthy.

As previously stated the sections of a round are bounded by trees bearing painted numbers; the catchers are supplied with tubes bearing numbers corresponding to those of the trees. Thus, when the boys reach the end of the 5th section, they see Tree 5 and know that they have to place their flies in tube 5. To prevent their skimping the work, or failing to visit all the sections, just before starting on the round they are given some sign which has to be carved on each of the numbered trees. Thus, when the round is next visited by the writer, he can, by looking at the symbol, make certain that each boundary tree has been passed. Half of the readings are made personally; thus each round is visited once in a period by an officer.

It is quite essential, however, that one should know one's rounds intimately, by constantly doing them oneself. It is only by doing this that one is able to get to know the small details which are so invaluable for checking native work. As an example of the type of checks utilised, in Sections 3 and 7 of Kikori N.E. round, some, if not most, of the fly will settle on the red earth path. Amongst the fly caught on these sections, one always finds grains of bright red soil, which have been swept up into the net during the catching of the tsetse and thence transferred with the fly into the tube. One section will be characterised by an abnormally high female percent; another by yielding a catch containing some specimens of *G. swynnertoni* from a neighbouring belt of this species. By knowing their characteristics, the writer has evolved checks for all the sections.

It is found best to send one of the older fly boys, who has been chosen for his comparative reliability, with one much younger. Two boys are considered to be the best number to send on a round, as they are quite capable of catching as many as 1,600 flies in a day. Experiment has shown that a third boy adds little to the catch. To justify his inclusion he would have to cause an increase of half the previous catch, as when the numbers are reduced to *fly boy hours* or *fly boy yards*, the addition of an extra boy will cause a decrease in the fly-total of one-third (i.e., one will divide the total by three instead of by two).

It is considered imperative that the numbers of catchers should always be constant, as otherwise one is decreasing or increasing the attractiveness of one's bait by changing the size of the human target. On those rounds in which the writer and a boy are catching, the natives who are carrying instruments, etc., walk about 40 yards behind, because, were they in close proximity, they would create a large attractive factor. It is believed that even the addition of one person, who is not catching, may have

an influence in attracting more fly by the increased movement and size of the target ; also, the addition of another person in the column adds to the work of the two boys who have another bait to examine for settling tsetse.

The following is the method adopted by the two catchers : They walk about twenty yards in single file and then stop. The second boy having caught off the back of the first, both " about turn," so that the first can examine the back of the second. They then search the ground within the radius of a yard from where they are standing for fly that have alighted on grass stems or upon the ground. This is done by moving the net gently across the surface so as to disturb the fly, which may be very difficult to see, until they have betrayed their whereabouts by movement. Having finished, the catchers then walk another twenty yards and repeat the performance. The duration of each stop depends upon the density of the fly, and will vary from about half a minute to two minutes.

The writer has always observed, when catching fly, that on first stopping there is a hum of tsetse around one, and that as one catches fly after fly the noise decreases, until none are to be seen. This is called the *first burst* of fly. Should one remain standing after this, odd fly will appear at comparatively long intervals. This first burst takes about a minute to catch, or two minutes if the density be high. In planning the method for the fly-rounds, the writer was anxious to catch this first burst of fly and not to await the occasional tsetse that appear afterwards. For this reason the method employed is so designed that the stops last until the last fly of the first burst has been captured, and then, when the lull occurs, the boys walk on.

This first burst of fly is taken to represent the *apparent* density in the immediate vicinity of the catch, or the *apparent* local fly population in the bush which is being tapped. Those fly which may arrive, one by one, after the first burst is over, are considered to be stray hunting tsetse that are roving through the bush in search of food. These fly may have come some miles, and may have originated from some entirely different type of vegetation community, and hence are not wanted. As Messrs. W. H. Potts and C. H. N. Jackson, working in the Western Kondo fly belt, have shown that such fly keep drifting in for some hours, to catch them would be entirely impracticable. At this point it may be as well to state that no pretence is made of obtaining figures of the *true* fly density. Fly-rounds can only yield an *apparent* fly density. An individual may have become gorged with blood half an hour before the catchers arrived, and hence, being inactive, will fail to come to the net. Again, the catchers may miss a fly, or the day may be very wet and the fly population quiescent. As will be shown later, however, comparative examination of a series of apparent density statistics, taking into consideration any abnormal days, can give very interesting information.

Whenever the writer uses the term " fly density " he is referring to the *apparent* density, and only when he mentions *true* fly density does he refer to the actual number of fly existing in an area.

The routine of stopping every twenty yards, whether a fly is seen or not, is enforced for the following reasons : It has been noticed in places of thin fly, that, by the catchers continuing to walk and stopping only when a tsetse is observed, many fly will be missed. Often tsetse will follow a moving object and will settle only when the object stops. Should the times between the stops be long, the fly will often cease to follow, being apparently in no need of food, but simply attracted by the moving object. The reason for this tropism is not known, but that it is not always hunger is certain, because fly that can have fed only a few hours before, and the bodies of which are filled with partly digested blood, are often caught in large numbers, and may form a very large percentage of the catch.

A typical fly-round form is given (Table III) to show the type of data that has been kept. The spoor of game judged to have been made less than twelve hours

TABLE III.
Kikori South-East Round.

Box Num- ber	Males	Fe- males	Total	Preg- nant fe- males	Fresh fe- males	Fresh fe- males	Duration	Time of day	Weather during catch	Game	State of grass, etc.	Hum- idity %	At- mos- pheric temp.	Wind in ft. per min- ute
I	2	2	4	0	0	2	12 mins.	4.22 p.m. 4.10 p.m.	Warm sun	—	Grass green, crops har- vested	50	71°F	225
II	33	6	39	0	12	3	27 mins.	4.9 p.m. 3.42 p.m.	Warm sun	Spor of lions	Grass turning	50	71°F	211
III	18	6	24	1	6	3	12 mins.	3.40 p.m. 3.28 p.m.	Warm sun	—	Grass turned; <i>Combretum</i> green	47	72°F	209
IV	117	13	130	1	28	11	67 mins.	3.24 p.m. 2.17 p.m.	Hot sun	—	Grass dry; <i>Berlinia glo- biflora</i> & <i>Brachystegia microphylla</i> green	46	71°F	146
V	30	2	32	0	8	1	15 mins.	2.15 p.m. 2.0 p.m.	Hot sun	Spor of 1 rhinoceros	Ditto	49	70°F	329
VI	58	26	84	2	26	13	44 mins.	1.59 p.m. 1.15 p.m.	Hot sun	Herd of zebra seen	Grass dry; <i>Combretum</i> turning	53	70°F	364
VII	44	9	53	1	18	5	23 mins.	12.11 p.m. 11.48 a.m.	Hot sun	—	<i>Berlinia</i> turning; grass dry	60	68°F	110
VIII	177	38	215	2	79	23	64 mins.	11.47 a.m. 10.45 a.m.	Hot sun	1 Roan seen	Grass dry; <i>Acacia usam- barensis</i> green	63	67°F	192
IX	60	48	108	0	26	20	54 mins.	10.40 a.m. 9.46 a.m.	Warm sun	2 zebra and 2 eland seen	Grass dry	63	66°F	297
X	22	6	28	0	4	2	30 mins.	8.22 a.m. 7.52 a.m.	Bright sun	—	Grass just turning; <i>Ac. usambarensis</i> green	78	62°F	210
Total	561	156	717	8	207	83								

Date	Last night's min. temp.	To-day's max. temp.	Yesterday's weather	Head of round
17.vii.28	56° F.	75° F.	Overcast till 11 a.m. Then sun and cloud	T. A. M. Nash

General Remarks:—The total density has fallen considerably.

before, only, is recorded. The head-boy on the unsuperintended round is always one who knows the spoor of the various species of game ; he is supplied with paper on which the numbers of all the trees of the round are written, having blank spaces opposite the numbers. On reaching a numbered tree, the fly are put in the tube bearing the corresponding figure, and the game news is written opposite the same number on the paper.

The method employed by investigators of *Glossina palpalis* to ascertain the apparent fly density was, briefly, as follows : The catchers would stand at a suitable spot on the lake-shore, and net all the fly that came to them in a given period. The figures would be reduced to flies per boy-hour and the apparent densities of different localities contrasted.

This method was employed for *G. morsitans* by certain workers, hour catches being made in different areas of bush. Though doubtless the original method employed was very satisfactory when dealing with *G. palpalis*, it is considered that this method is most unsuitable for *G. morsitans*. For this reason the writer evolved this present technique for fly-rounds. He considers his method for the study of an insect such as *G. morsitans*—which is distributed throughout the bush and is not restricted to the vicinity of water—to be more suitable for the following reasons :—

1. An hour's catch repeated six times a month in the neighbourhood of a certain tree would probably have a serious catching-out effect upon the natural fly density at that spot. By passing through the area in a straight line, however, the fly which are resting at some small distance from the path are probably not attracted, so that there are tsetse left on each side, ready to drift in to fill the small displacement caused by the catching.

2. If one constantly stops for hour or half-hour catches, the area which can be investigated will be much smaller than if one is following a definite route, and catching all the time.

3. Clearly, by spending half an hour at a certain spot in a wood, one will not get such a true indication of its fly population as by walking through it for a similar period of time.

4. An hour's occupation of a piece of bush is more likely to scare the game, than a mere passage through it.

5. When catching for an hour in one locality, the bulk of the fly are removed in the first few minutes ; the rest of the time is spent in walking up and down and catching an occasional fly at five to ten minutes intervals. This is extremely monotonous work and, owing to the length of the intervals, it is difficult to keep alert for any fresh arrivals.

6. Lastly, the catching near one spot for a given period does not yield nearly such high figures as those obtained by continuing to tap fresh country for a similar time.

It has been found that high figures are essential if comparisons are to be made of the apparent fly densities for different seasons, and for different types of vegetation.

Up to the present tsetse workers have employed the unit "flies per boy-hour" (F.B.H.) when they wished to compare the relative, apparent fly density of two areas. The writer considers this unit to be fallacious when used in an investigation upon *Glossina morsitans*. When fly reconnaissance is being carried out in an unknown area, and when each part of the country will be traversed on one occasion only, figures produced in the form of F.B.H. may be of some scientific value ; but when accurate work is being attempted in a fly belt for months at a time, this unit is too fraught with error to yield results of much scientific worth.

In the old unit of F.B.H. the factors flies and boys are as satisfactory as is possible, considering that one is unable to obtain a true density, and that natives have to be employed to help in the catching. The time factor, however, is considered to be fallacious. The supposition that the time taken depends upon the density of the fly is incorrect. The time factor varies according to many minor factors, only one of which is the density of the fly. The two most important minor factors that cause large error in the "time taken" are the fly activity factor and the human factor.

With regard to the fly activity factor, workers on the tsetse problem, who have themselves caught large numbers of *Glossina morsitans* with the usual type of small net, will probably agree with the following statements with regard to fly behaviour.

1. Often *G. morsitans* is extremely easy to catch, so that as many as five may be taken in one sweep of the net, the catcher being kept hard at work, catching and killing as fast as he is able.

2. At other times most of the fly will settle on the ground or grass stems around, instead of upon, the bait. This will necessitate laborious searching for each individual fly, and the catching rate will be slow in consequence. Should there be a large emergence of young fly the rate of catching will be extremely slow owing to their liveliness and to the skilfulness with which they avoid capture. Freshly emerged fly also are very persistent. A young fly may do one of two things: either it may fly to the other side of its prey, the moment that it sees a movement of the net, and the catcher may have to follow it around and around the stationary boy, and then lose sight of it because it has settled on his own back; or it may lie flat on the surface of the bait, failing to rise as the sweep of the net approaches. This results in the net rim hitting the fly, but the insect is so close to the surface that it fails to enter the net-bag. Young fly appear to be capable of withstanding the shock of being struck by the wooden net frame without being driven away. A fly of this type can only be caught by placing the whole surface of the net on top of it, and then groping through the muslin with the fingers in order to capture it. Freshly emerged fly appear to like dark places, such as underneath the brim of the helmet or between the legs. These peculiarities of young fly increase the time taken to capture them.

3. Occasionally all the fly, both young and old, are extremely lively and troublesome to catch. This is often the case on the approach of a heavy rain storm.

At those times when the fly are hard to catch, the time taken on a certain section of the round will be much longer, not because of an increased density of fly, but because of an increased activity. For example, take two sections of equal length. Trees 3 to 4. Fly easy to catch; 60 flies in 28 minutes. Trees 9 to 10. Fly hard to catch; 60 flies in 33 minutes.

On reducing one's results to flies per boy hour, one will naturally find that Section 3 to 4 has an apparently greater density than 9 to 10—an absolute fallacy, as increase in time for the latter catch was not due to this section having a greater density of fly than Section 3 to 4, but to its having, say, a much higher percentage of freshly emerged fly, which hence took longer to catch.

With regard to the human factor, also, the two following points may be noted:—

1. If the day is hot, and the catchers tired, they will take appreciably longer to complete the section, because they are walking more slowly than they did on a previous occasion when they visited this section in the cool of the day. Again, increased time not due to density of fly, but to fatigue of catchers.

2. On the day the round is done forwards, *i.e.*, starting at Tree 1 in a certain section, a long hill is descended. On the day the round is done backwards, *i.e.*, starting at Tree 12, this hill has to be climbed, which naturally takes longer. Another human factor of error.

There are many more similar types of error that cannot be gone into here. These errors still arise even if it be decided to catch for exactly one hour, along a certain path. Here, although one has steadied the time factor, one has now unbalanced the "number of fly" factor; e.g., one day is characterised by an increase in freshly emerged fly. Owing to the difficulty of catching these individuals, a shorter distance than usual will have been traversed along the path before the time limit has expired, and hence many fly further ahead will not be caught on this day. Thus an artificial impression of decreased density will result. In other words, if the time be constant, the apparent density will be varied by the activity of the fly.

As a remedy for these sources of error it is proposed to form an entirely new unit, which will express the difference in fly density of two sections so that they can be compared. The following expression, "fly per boy-yard" is suggested. This principle is easy to work when the catches are being carried out along fixed rounds from one numbered tree to another, with a small path connecting all the sections. It is no great task to measure the length of the path connecting two sections, and once measured one has a constant unvarying factor. This method, of course, could not be employed on an extended preliminary fly survey, where one would pass along the same route once only. For such rough work the old "flies per boy-hour" unit is quite accurate enough.

By this new method one section can be conveniently compared with another, by reducing the distance for each to unity, so that the "beats" are comparable. Thus it will not matter, within reason, how long is taken to catch the fly, and all the above errors will be eliminated. The number of fly caught is dependent to a large extent on the length of bush that is tapped. If this length is constant, then the only variable quantity can be the apparent density of fly. Thus one will get an expression that, when reduced, will tell one, for example, that the figures for 1928 to 1929 show that the average density of *G. morsitans* for *Brachystegia* is 0.6 flies per linear yard, whereas for *Acacia usambarensis* it is 0.4 flies per yard.

Example:—

- A. Trees 1 to 2, 600 yards apart: *Brachystegia* wooding on 2. viii. 28 yielded 400 flies, two boys catching.
- B. Trees 8 to 9, 200 yards apart: *Acacia spirocarpa* wooding on 2. viii. 28 yielded 250 flies, two boys catching.

It is desired to compare the relative densities of the fly in these two types of vegetation.

$$A. \quad \dots \quad \frac{400}{600 \times 2} = \frac{1}{3} \text{ fly per boy yard} = 0.333 \text{ F.B.Y.}$$

$$B. \quad \dots \quad \frac{250}{200 \times 2} = \frac{5}{8} \text{ fly per boy yard} = 0.625 \text{ F.B.Y.}$$

Hence in unit length of wooding of *Acacia spirocarpa* the fly density was greater than in the same length of *Brachystegia*.

FLY-ROUND RESULTS.

The North-East Kikori Round, 1928 (fig. 1).

- | | | |
|------------------|-----|--|
| Camp to Tree 1. | ... | Cultivation. |
| Tree 1 to Tree 2 | ... | Old cultivation, now overgrown with grass and shrubs. |
| Tree 2 to Tree 3 | ... | Native path through <i>Combretum</i> savannah, with other savannah species. |
| Tree 3 to Tree 4 | ... | Having left path, <i>Combretum</i> savannah, with other savannah species and a little <i>Berlinia globiflora</i> . |

- Tree 4 to Tree 5 ... Pure stand of *Acacia usambarensis*, with tall grasses.
- Tree 5 to Tree 6 ... As for 4, but substitute *Brachystegia microphylla* for *Berlinia*.
- Tree 6 to Tree 7 ... Native path through *Combretum* savannah, having, as well, scattered *B. microphylla*, and a few *A. usambarensis*.
- Tree 7 to Tree 8 ... In the bush—*A. usambarensis* with underwooding of *Combretum zeyheri*.
- Tree 8 to Tree 9 ... A *Brachystegia microphylla* community, following the sides of a hill.
- Tree 9 to Tree 10 ... As for 9, but along water-shed of hill.
- Tree 10 to Tree 11 ... Impure *Combretum* savannah containing *Commiphora* sp., *Vitex* sp., *Lannea humilis*, and *Parinari* *curatellaefolium*.
- Tree 11 to Tree 12 ... *Acacia campylacantha* and *A. xanthophloea* bounding a moist thicket.

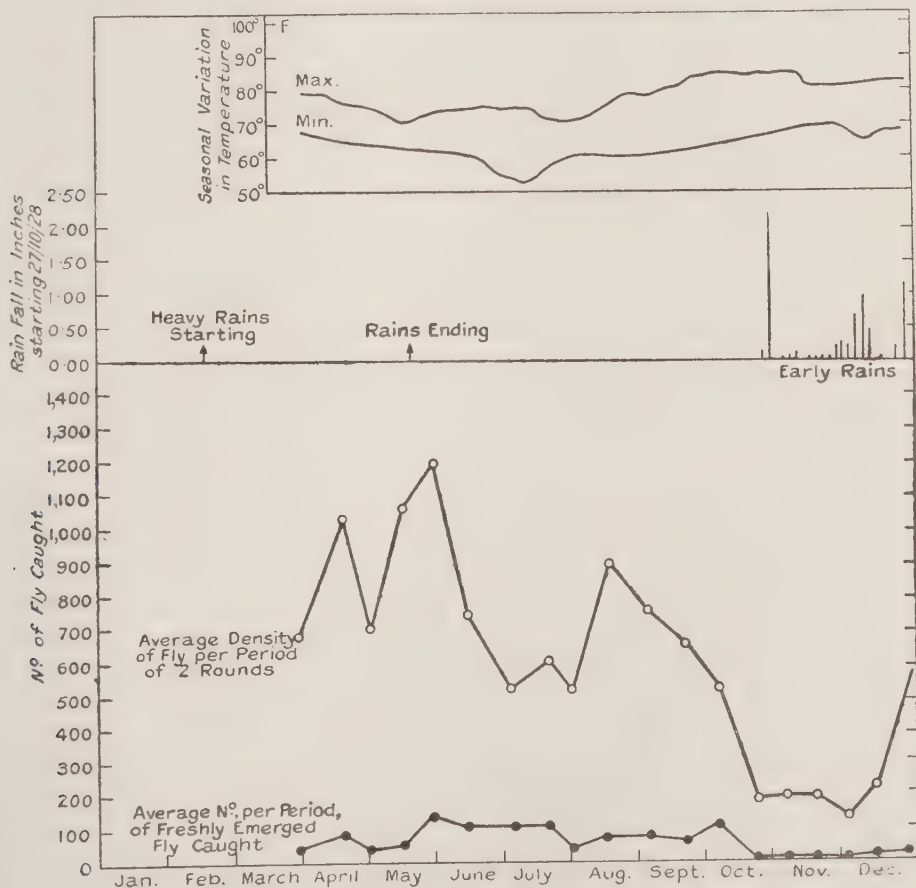


Fig. 1. The N.E. Kikori Round, 1928,

This round was started on 29th March 1928. During the latter part of the heavy rains, mid April, the fly density temporarily rose, but by early May it was approximately the same as in late March. No attempt will be made to explain this, as at the time the writer had only just started to investigate the factors that govern the fluctuations of fly density.

The rains ended about 18th May. Coincident with this was the large increase in fly emergence resulting in a rise of total density. The cessation of the rains appeared to be the signal for many dormant fly to leave their puparia. The maximum density was reached by the end of May.

The nights became colder, until the period of minimum temperature was reached on about 3rd July. This drop in temperature was steadily followed by a fall in density, until a figure was reached lower than that obtained before the cessation of the rains. Despite this great drop in density during the cold spell the number of freshly emerged fly remained almost as high as at the end of the rains. Hence cold, or some factor correlated with the cold spell, apparently reduced the total density considerably, but had practically no effect upon the density of the freshly emerged fly. The deduction is that the fall in density was due to the death of the old fly, which, having carried on throughout the latter months of the rains, were killed off by some factor correlated with the cold nights; this factor, however, would appear rather to stimulate than to check the emergence of fresh fly. Unfortunately, no results upon the relative susceptibility to cold of old and young flies are available.

The emergence of fresh fly did not decrease until the end of July, when the nights were becoming appreciably warmer. By mid-August the cold spell was over, and once more the numbers of fresh fly started to increase. In early September there was a slight drop in the total density.

On 9th September a large portion of the N.E. fly-round was burnt. A catch on 10th September produced rather more fly than on 8th September—the day before the fire. From this fact, and from observations which showed that the fly had fled in front of the fire, and had settled on the edges of the burnt area, it is indicated that the fire did not reduce the fly density, but caused temporary concentrations, in what had previously been an area of relatively uniform fly distribution. The fire caused displacement, not destruction, of the fly. Immediately after the fire there was no reduction in total density, but a month later there was a considerable diminution in numbers, and seven weeks later—end of October—the pre-fire density of 750 had dropped to 200. The fire may have caused this effect either directly or indirectly.

Firstly, the burn may have directly affected the fly community by destroying large numbers of puparia that were lying in or under dry logs. In support of this possibility—certain fallen tree-trunks were known to be harbouring several hundred puparia, prior to the fire; as many as 300 full cases had been counted in the humus of one rotten trunk. The fire destroyed these breeding sites so completely that they were converted into nothing more than heaps of ash. On the supposition that once the existing population had died, there would be an abnormally small number of freshly emerged fly to take their place, one can account for the lag that occurred between the burn and the main drop in density. Against this possibility—the number of freshly emerged fly did not fall after the fire, but slightly increased.

Again, the burn may have indirectly affected the fly community, by changing the environment and making it unsuitable for a thriving fly population. After the fire, the country was devoid of shade; the trees were leafless, and there was no grass; also many logs and suitable breeding-places had been destroyed. The adult fly community existing at the time of the fire may have suffered a curtailed longevity due to adverse environmental conditions. There may have been a high mortality among their puparia, owing to lack of suitable breeding sites, which would have

accounted for the drop in numbers of freshly emerged fly that occurred six weeks later. This indirect effect upon both adults and their puparia also would account for the *gradual* decrease in fly density. The Kandaga round, which was protected from fire, showed that the great drop was not seasonal, as the control retained a steady density from mid-September to mid-October.

From just before the commencement of the early rains in late October until mid-December, the fly density, and numbers of freshly emerged fly, remained at an extraordinarily low level. This was the minimum season for *G. morsitans* as compared with the optimum that occurred at the end of the rains. It was not until mid-December, when the early rains had spent their force and the number of wet days was becoming fewer, that the fly density started to rise. By early January the density had risen by 500.

There is no corresponding rise on the graph for the numbers of freshly emerged flies; this does not mean that no emergence took place. On the contrary, it is exceedingly probable that there was a large emergence, and that it occurred during the ten day interval between two periods of the fly-round, and so was not noted. Sudden bursts of emergence may often take place, and last for a couple of days only; these must often be missed by the fly-rounds.

The South-East Kandaga Round, 1928 (fig. 2).

Camp to Tree 1 ...	Native clearing and cultivation.
Tree 1 to Tree 2 ...	Clearing. Many dying ring-barked trees.
Tree 2 to Tree 3 ...	Native path through large trees of <i>Derris violacea</i> , <i>Kigelia</i> , and <i>Acacia</i> with a <i>Combretum</i> under-storey.
Tree 3 to Tree 4 ...	Native path through open mbuga, with a few gall acacias.
Tree 4 to Tree 5 ...	Native path through <i>Berlinia</i> at first, and then through a transitional belt.
Tree 5 to Tree 6 ...	Native path through <i>Berlinia</i> only.
Tree 6 to Tree 7 ...	On leaving path, through pure <i>Berlinia</i> .
Tree 7 to Tree 8 ...	<i>Combretum-Terminalia</i> "mbuga."
Tree 8 to Tree 9 ...	Orchard bush.
Tree 9 to Tree 10 ...	<i>Berlinia</i> wood becoming very dense.
Tree 10 to Tree 11 ...	Small thicket.
Tree 11 to Tree 12 ...	"Mbuga" with <i>Combretum-Terminalia</i> , <i>Lannea humilis</i> and <i>Acacia senegal</i> .
Tree 12 to Tree 13 ...	Open grass "mbuga" with occasional <i>Acacia spirocarpa</i> .
Tree 13 to Tree 14 ...	Gall acacias thickened with <i>Commiphora</i> sp. and <i>Acacia senegal</i> .
Tree 14 to Tree 15 ...	Thin gall acacias bordering open grass "mbugas."
Tree 15 to Tree 16 ...	Glade in thicket (much <i>Dalbergia melanoxylon</i> present).
Tree 16 to Tree 17 ...	<i>Combretum-Terminalia</i> wooding.
Tree 17 to Tree 18 ...	<i>Acacia spirocarpa</i> with gall acacias underneath.
Tree 18 to Tree 19 ...	<i>Acacia spirocarpa</i> and <i>A. usambarensis</i> bounded at each end by a thin strip of <i>Combretum</i> wooding.
Tree 19 to Tree 20 ...	A clearing.
Tree 20 to Tree 21 ...	Cultivation.

N.B.—Gall acacias may be either *A. formicarum* or *A. drepanolobium*.

Owing to the much smaller number of fly involved, this graph does not demonstrate salient features of the round in such a diagrammatic fashion as did the N.E. Kikori round. Close examination, however, does show that its interpretation is similar.

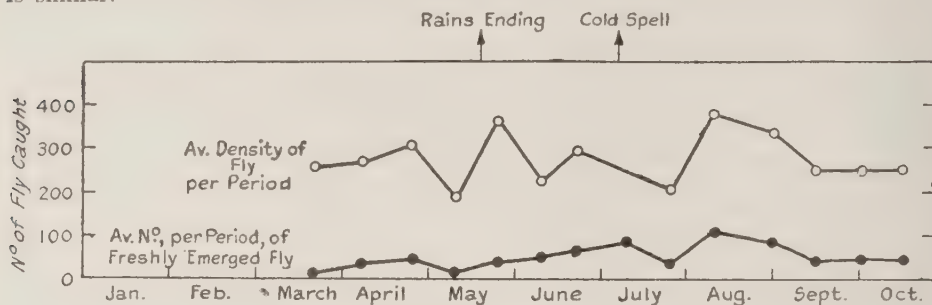


Fig. 2. The S.E. Kandaga Round, 1928.

There are a few points of apparent dissimilarity. At the end of the rains, the curve for freshly emerged flies did not rise *abruptly*, and did not remain steady, until after the period of minimum temperature (3rd July), as on the N.E. Kikori round; instead, it rose *gradually* until 9th July, and then fell. This, however, is a matter of degree, not principle. The curves, both for density and the numbers of fresh fly, rose at the end of the cold spell in early August and remained similar to those of the Kikori round, until the latter was burnt in early September; then, whilst the density was falling rapidly on the burnt Kikori round, on the control it was remaining steady.

Unfortunately the Kandaga round had to be given up, owing to shortage of staff in mid-October.

The South-East Kikori Round, 1928 (fig. 3).

Camp to Tree 1 Cultivation.

Tree 1 to Tree 2 ... Native path through *Combretum* and other savannah shrubs on the one side, and cultivation or grass clearing on the other.

Tree 2 to Tree 3 ... Native path. *Combretum* to *B. microphylla* transition on west side, and *Combretum* savannah continuing on east.

Tree 3 to Tree 4 ... Native path through *Berlinia* sp. and *B. microphylla*.

Tree 4 to Tree 5 ... Strip of bush through *Berlinia* sp. and *B. microphylla*.

Tree 5 to Tree 6 ... *Combretum* savannah and other savannah spp.

Tree 6 to Tree 7 ... Thick *Berlinia* sp. with a little *B. microphylla*.

Tree 7 to Tree 8 ... *Acacia usambarensis* with *Combretum zeyheri* underwooding.

Tree 8 to Tree 9 ... Open "mbuga" with thin wooding of gall acacias and *Acacia seyal*, i.e., typical open "mbuga" country.

Tree 9 to Tree 10 ... As for Tree 8.

N.B.—The local term "mbuga" is used for any low-lying land characterised by the cracking black cotton soil. This soil may become water-logged in the rains, and cracks in the dry season.

The vegetation communities tapped by the Kikori fly-rounds are shown on the sketch-map.

This round conforms to the N.E. Kikori type, except when influenced by game concentrations. The game factor plays a very great part in the fluctuations of its fly community. The great game movements, dictated by water shortage, are centred in the country traversed by this round; the N.E. round is hardly affected by animal migrations.

The S.E. Kikori fly-round preserved a medium density, with low emergence of fresh fly, during the heavy rains; at their close there was a great emergence of young fly, and the total density soared. As the nights became colder the density dropped; but the emergence continued to increase. Towards the end of the cold spell, the numbers of freshly emerged flies dropped; then, in mid-August, when the density should have increased, both curves fell. This was the first fundamental difference between the two Kikori rounds. It was due to the drying of water-holes and the complete migration of game, just when the density should have risen at the return of the warm weather.

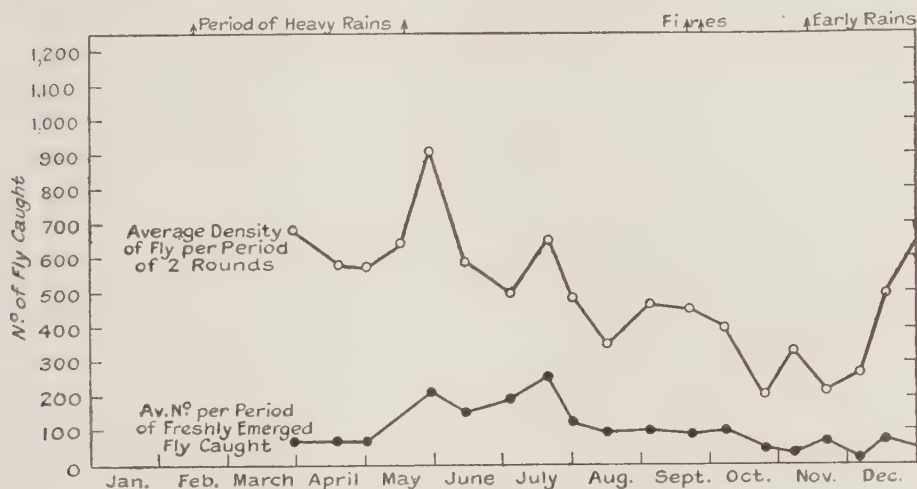


Fig. 3. The S.E. Kikori Round, 1928.

The density continued to drop until some game returned in early September, when it rose and remained at the same level until the advent of the fires in late September. Here again, the drop in fly density started slowly, but fell rapidly after a few weeks. The curve for freshly emerged fly also exhibited a similar lag.

From just before the commencement of the early rains, until their force was spent in mid-December, the fly density and density of young fly were both exceedingly low. This was the minimum season for *G. morsitans* on this round also. By early January the density had risen by nearly 500; but here again the fly-round missed any burst of emergence that may have taken place.

The North-East Kikori Round, 1929 (fig. 4).

The rise in fly density that started in mid-December, 1928, reached its maximum in early February, 1929, at the very end of the early rains, which had been "petering out" for the last six weeks. A burst of emergence was also recorded at this time.

The short dry season occurred during February. The temperature rose to about 105° F. in the shade, and the humidity dropped to 12 per cent. The grass shrivelled,

and there was a recurrence of bush fires. During this period of intense climatic conditions, the fly density, and numbers of freshly emerged fly, steadily dropped. The fall was checked only by the advent of the heavy rains in late February. The

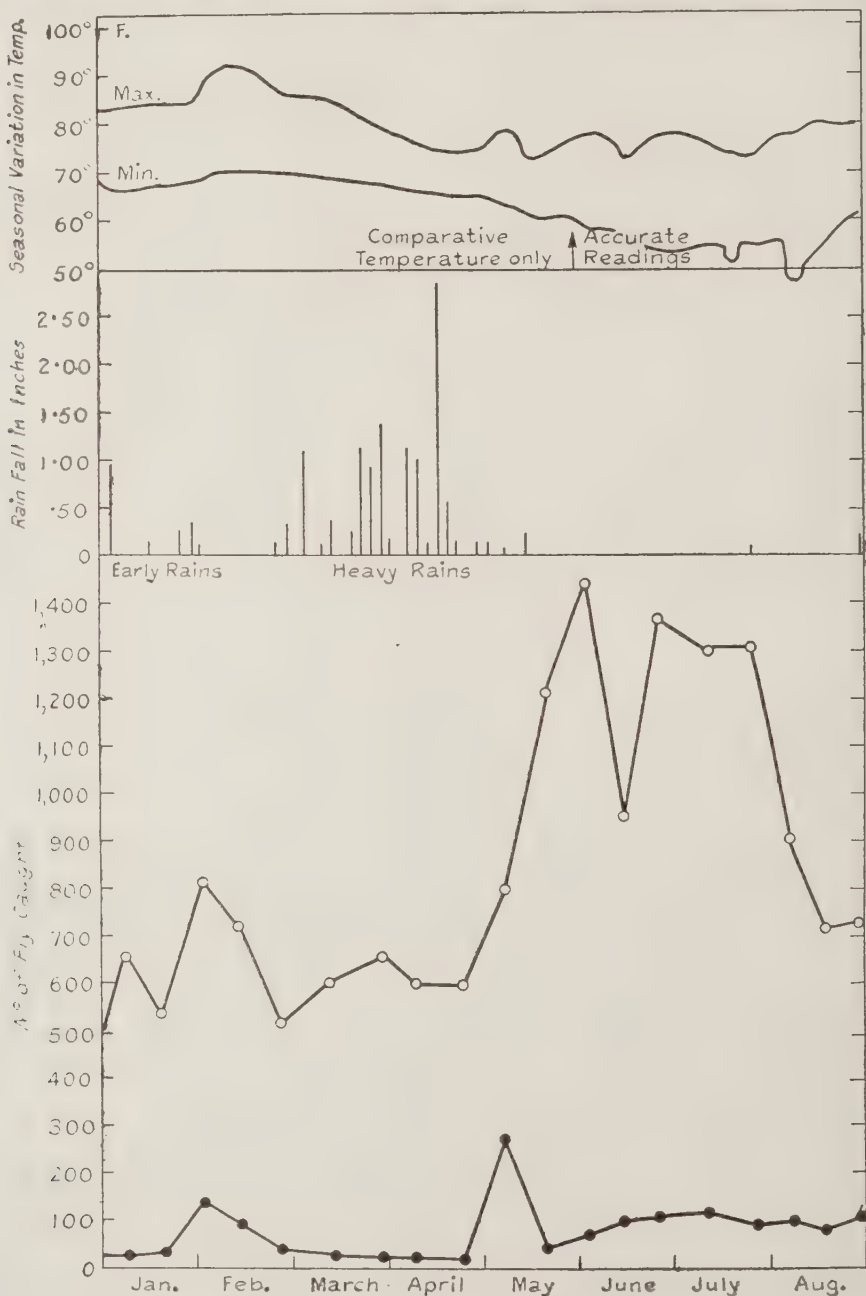


Fig. 4. The N.E. Kikori Round, 1929.

density increased slightly and then remained at a medium steady level for the rest of the rains. During this period of sodden soil conditions, the emergence of fresh fly was very small.

In late April the rather meagre heavy rains came to an end. Once again the cessation of the rains was the sign for a tremendous burst of emergence; by mid-May the total density had doubled itself. By early June, the average catch of the two rounds, which make a period, had reached 1,450 flies, one of the days yielding 1,650 flies. This year the rise in the numbers of freshly emerged fly was in the nature of a burst, not of a gradual increase. In early May the number of young fly dropped to a more reasonable level, and thence continued to rise steadily. Clearly emergence was much greater after the rains than during the rains.

This year, owing to the poorness of the "heavy" rains, the ground dried up very rapidly, and possibly this enabled the flies to emerge from their puparia *en masse*, thus creating a burst of young fly. The consequence of such a great emergence in a short period was an inevitable drop, as fresh flies could not continue coming out in such large numbers over a long period of time. Last year, owing to the heaviness of the rains, the drying up of the soil was a process that took a considerable time, and certain areas, being almost water-logged, took longer than others. Possibly this was the reason for the more gradual emergence of fly, and the consequent absence of a sudden drop in numbers of young individuals shortly afterwards.

In mid-June the density curve suddenly fell. This was merely a fall due to decreased fly activity owing to the overcast, damp weather conditions prevailing on both days of the fly-round. There had been a slight return of the rains, and both of these days were characterised by drizzle and lack of sun. By the end of June the density stood at its previous high level and remained steady until early August. This year the spell of intensely cold nights was more than a month late, and accordingly the period of great fly density was protracted. Very low temperatures were not recorded until 6th August. Coincident with the cold was a dramatic drop in fly density. Again, some factor correlated with the cold appears to have killed off the old fly, since the number of freshly emerged tsetse was hardly affected. By mid-August the fall in density had checked.

N.B.—The temperature curve on the graph for the cold spell of 1928 (fig. 1) gives the comparative seasonal temperature only. The degree of cold should be ignored, since the readings for that year were taken from an inaccurate thermometer hung in a grass hut. The temperatures recorded for the cold spell of 1929 are accurate, since they were taken in a properly exposed meteorological station. It will be seen that, although the temperature fell to 51° F. in late July, the fly density was not affected till early August, when the minimum reached 48° F. At this time the temperatures recorded by the Ecological Station in their "mbuga" plots were much lower than those just quoted.

The South-East Kandaga Round, 1929 (fig. 5).

This round was re-continued in late January 1929, shortly after the appointment of an Observer to the station. As on the N.E. Kikori round, the density remained steady during the heavy rains, and the number of fly emerging was low. At the end of the rains the numbers of young fly steadily increased, and there was a tremendous rise in the total density. A burst of young flies may have occurred, but if so, it must have taken place during the fifteen-day interval between two visits. The total density rose to 800 fly, which is a great increase upon any figures obtained in the previous year. It remained at this high level until the end of July, when it commenced falling. By mid-August the curve had reached its lowest point, and after

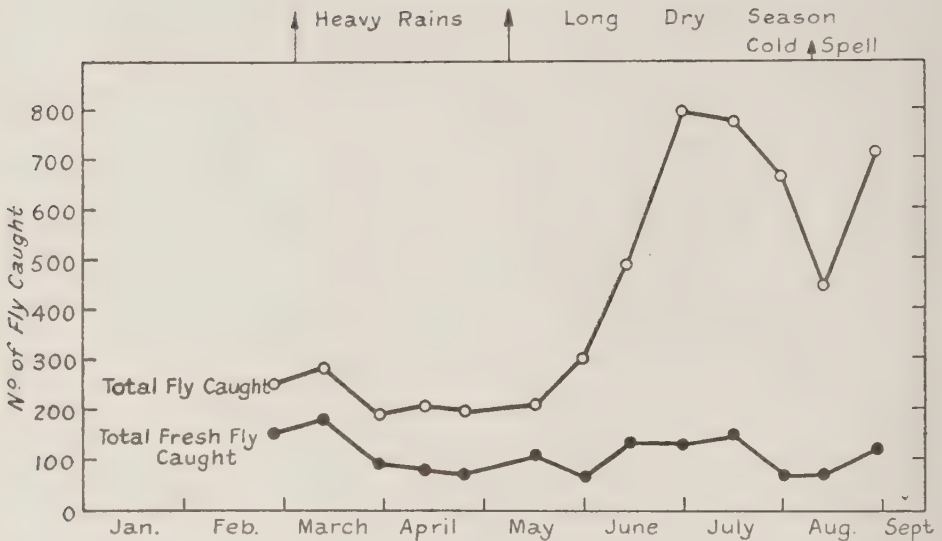


Fig. 5. The S.E. Kandaga Round, 1929.

this it rose. No instruments are kept at Kandaga, but it is significant that the drop occurred at about the same time as the cold spell at Kikori. The number of freshly emerged fly was definitely lower during this period.

The South-East Kikori Round, 1929 (fig. 6).

The rise in fly density that started in mid-December, 1928, continued until early January. There was then an erratic drop, which probably was due to decreased activity of the fly, consequent upon a few days of overcast weather. The density continued to rise until early February, when a great burst of emergence took place. During the extreme climatic conditions of this month, the density started to drop.

All these phases are similar to those experienced on the N.E. Kikori round; however, instead of the fall in density continuing throughout the short dry season, it stopped in mid-February and started to rise rapidly.

This rise corresponded with the arrival of large herds of game, which had been forced in from Masai land because of the drought. This was the biggest game movement during the year. The density reached its maximum in mid-March, just after the game had started to disperse. During this period the number of freshly emerged fly was extremely high, unlike the N.E. Kikori round. By late March the game had completely dispersed, with striking results upon the fly community. The density fell with great rapidity, until it had been reduced by half; similarly there was a big drop in the numbers of young fly.

This marked fluctuation in the fly community is considered to have been artificially produced by the game factor. The striking rise in density is believed to be due to the fly attracted into the area by the herds of game concentrated within the round, and not to an increase in density of the local fly community. Similarly it is possible that the increase in numbers of freshly emerged fly was not due to an increased emergence, but to the young fly of the district being attracted into the S.E. round in pursuit of the game. The writer has some evidence for believing that,

at first, young fly are principally engaged in searching for animals, in their efforts to obtain their first feed of blood, which appears to be essential for the hardening of their tissues.

In April much work was started in the core of the round by the members of the Ecological Station, who were clearing plots for the erection of meteorological apparatus. This meant that large bodies of natives were working within the area, cutting poles and carrying loads. In addition, lorries would follow bush tracks down to the plots. At the time game was scarce in the area, and the fly are believed to have left the country traversed by the fly-round paths, and to have concentrated around the plots where there was a constant human food supply. Whatever the reasons may have been, it is clear from the graph, that from this time onwards the fly community was completely disturbed. The curves fluctuated without any

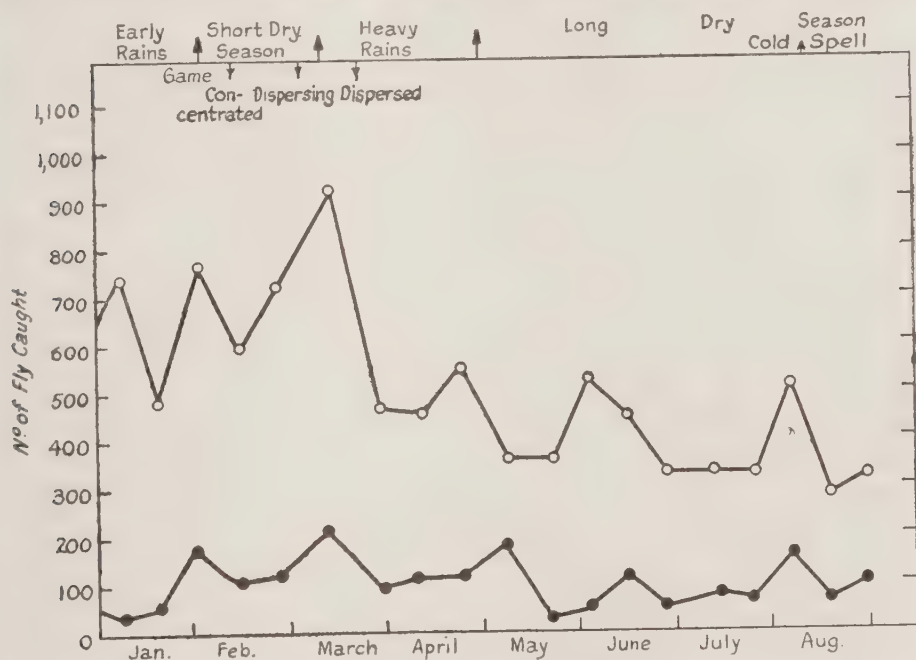


Fig. 6. The S.E. Kikori Round, 1929.

apparent reason, and showed no similarity with either the Kikori N.E. round or the Kandaga S.E. round. At the end of the rains, when the density rapidly increased on the two unaffected rounds, on this one the numbers of fly rapidly decreased. A drop occurred at the time of the cold spell, but the writer does not consider this of value, owing to the disturbed conditions prevailing in the area.

The information produced by these fly-rounds has thrown light upon the three great factors that govern the bionomics of *G. morsitans*:—The seasonal factor; the vegetation factor; and the game factor. Each will be dealt with separately.

The Seasonal Factor.

Major Effects.

The accompanying graph (fig. 7) is hypothetical; it has been constructed from the common features of the three fly-round graphs. It is intended to illustrate the

writer's concept of the effect of season upon *G. morsitans*: the fluctuations due to the game factor have been eliminated. This was rendered possible by using the statistics from the N.E. Kikori and S.E. Kandaga rounds, which are not seriously affected by game movements. The upper curve represents the apparent fly density, and the lower, the number of freshly emerged fly.

The Apparent Fly Density.—1. At the end of the light rains, there is a considerable increase in the density of fly.

2. Throughout the rigours of the short dry season the density drops.

3. At the commencement of the heavy rains the density increases and then remains steady at a fairly high level.

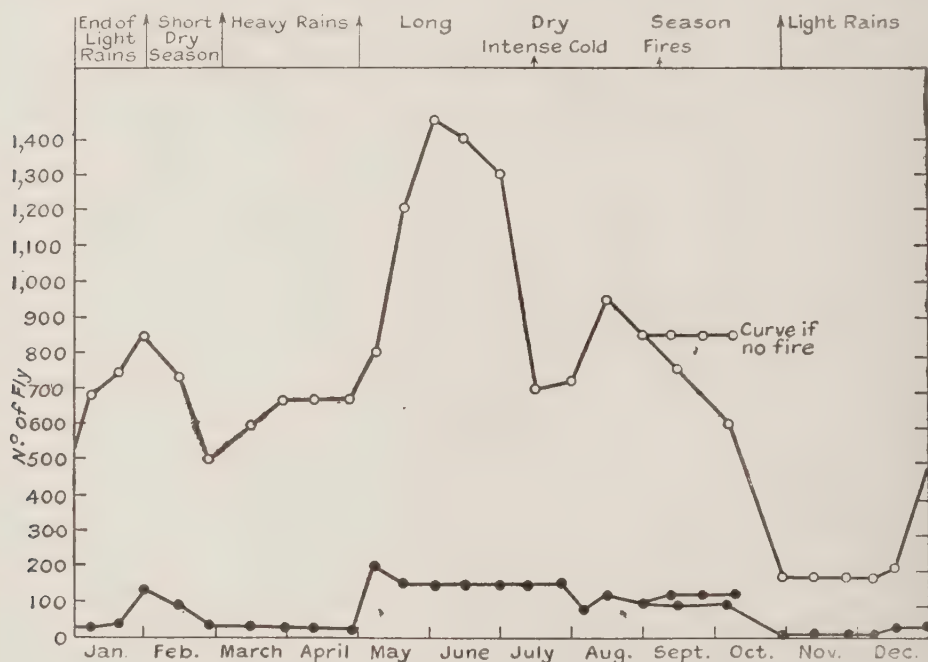


Fig. 7. Hypothetical graph of effect of season upon *Glossina morsitans*.

4. At the end of the rains the density greatly increases. It remains high throughout the early part of the long dry season, and falls only on the arrival of the relatively intense cold. The density rises when the weather becomes warmer.

The September fires can be considered as part of the season, as they are regular phenomena in the country. At first they have little effect upon the density, but afterwards the number of fly steadily decreases, until an exceedingly low level is reached.

5. During the early part of the light rains fly density remains very low. It is not until these rains are almost over that a rise takes place.

Emergence of Fly.—The graph shows clearly that the emergence of fly is very low, during both light and heavy rains. At the end of each, the number of young fly increases. Generally speaking the emergence of fresh fly takes place during the short and long dry seasons.

Minor Effects.

The time of day and weather during catch have a distinct bearing upon the fly density, and upon the sex ratio. Their effect varies according to the season.

Effects upon density.—Following are four excerpts from fly-round forms, which demonstrate the variations in apparent density according to the time of day and the season. (Table IV.)

Column 1.

This illustrates the inactivity of fly in the early mornings, as compared with their activity in the afternoons; the period dealt with is the cold spell of 1929. The two catches of the period are bracketed together and should be compared with each other. It will be seen that the early morning catch is very much lower than that of the afternoon, yielding a most erroneous figure, as compared with that of the afternoon, which gives a total more closely approximating to the *true* density. This is not due to the overcast conditions that prevail in the mornings, as it will be seen that large afternoon catches also were made under overcast conditions. This inactivity of the fly is considered to be due either to the low temperature, or to the high humidity per cent.; the matter will be discussed later.

Column 2.

This column compares the early morning figures with those of the late morning or mid-day, for the cold period of 1928, and the weeks immediately following. It will be seen that, after 10 a.m. the fly are active, and large numbers are taken. It should be noticed that despite the sunny weather conditions on certain mornings only very low densities were forthcoming.

By September 1928, the cold months were almost over, and the figures ceased to show a disparity between the early morning and mid-day catches.

Column 3.

These figures should be compared with those for Column 1. They deal with the same season and are taken from a section having the same vegetational community. Their difference is that Column 1 deals with morning catches made between approximately 9 a.m. and 10 a.m., whereas in Column 3 the morning catches are made between 10 a.m. and 11.45 a.m. (approx.). It will be seen from Column 3 that no marked disparity occurs between mid-morning and afternoon catches, whereas there was great disparity between those of the early morning and afternoon in Column 1.

Column 4.

This, also, should be compared with Column 1, as both deal with the same section; however, the figures for Column 4 are for the dry period covering the end of the early rains and the short dry season, whereas Column 1 dealt with the cold spell. It is evident that there is no definite disparity between the densities of early morning and early afternoon, as there was for the cold weather.

Conclusions.

These excerpts from the fly-round forms indicate that the fly community remains inactive until after 10 a.m. during the cold season, when minimum temperatures are recorded near dawn. From approximately 10 a.m. onwards the fly is active, and no great disparity in numbers occurs at any time between this and dusk. At other seasons in the year, there is no definite and regular disparity between catches made early in the morning and those made later in the day.

A regular disparity occurs during the cold spell only. It has also been shown that, at this season, low densities will be obtained before 10 a.m. whether the morning be overcast or bright.

On account of these results, all points plotted on the graphs represent the average of the two catches for a period; thus, to some extent during the cold spell one is able to neutralise the effect of the inactivity that occurs on the first few sections of a round.

The figures plotted on the density graphs from mid-June to mid-August are probably slightly on the low side; however, owing to the small proportion of the round that is covered before 10 a.m., this error is very small as compared with the total catch, and could not possibly account for the marked drop in total fly density that occurs during the height of the cold season.

During the cold spell of the last two years, the writer has observed that very few fly were seen on those sections done early in the morning. A time was reached, however, when the fly would begin to appear, and before long would be swarming about the catchers. With a view to finding the factor or factors causing this marked change in fly behaviour, readings were taken with a whirl psychrometer for each section. The readings for the last section in which fly were inactive, and for the first section in which fly were active, were collected from each round, and their averages taken (Table V).

TABLE V.

The last section in which fly were <i>inactive</i> .		The first section in which fly were <i>active</i> .	
Average Humidity per cent.	Average Atmospheric temperature	Average Humidity per cent.	Average Atmospheric temperature.
77 per cent.	64° F.	66 per cent.	67° F.

The variation in temperature between the two readings is not great, whereas the variation between the two humidities is large.

It often is stated that fly are more numerous in the evening than at mid-day. In the writer's experience, this is not the case; fly appear to be more numerous at that time of day because they come to feed and render themselves noticeable by their painful probing. In reality fly are just as numerous at midday, but at this time they are content to settle on the grass stems near the human bait, to swarm in the air around him, or to be carried along on his back without endeavouring to feed. In the statistics obtained during the last eighteen months, there is no indication of fly being appreciably more numerous in the evening than at mid-day.

Effects upon sex ratio.—It has been found that the time of day, between the middle of May and the end of September, has a distinct effect upon the sex ratio. This period coincides with the coldest months of the year. Throughout this period the female percentage was invariably higher in the early morning catches than in those of the mid-day or afternoon catches.

This is illustrated by the accompanying excerpt from a fly-round form; figures are also given for the weeks preceding and following the period, so as to show the irregularities that occur at other times (Table VI). It should be noted that the effect upon the sex ratio was most marked between mid-June and mid-July, which period coincides with the time of lowest minimum temperatures experienced in 1928. During the rest of the year the time of day has no apparent regular effect upon the sex ratio. In the cold spell of 1929, a similar result was obtained.

From these results we can deduce that the reduction of fly activity in the early mornings during the cold spell does not apply to the females to the same extent as to the males, because the female per cent. is higher in the morning than in the afternoon.

TABLE VI.
Section X, South-east Kikori Round.

Date	Total fly	Female per cent.	Time of day	Date	Total fly	Female per cent.	Time of day
29.iv.28 ...	129	0.7	8.03 a.m. 9.15 a.m.	4.ix.28 ...	113	2	2.50 p.m. 4.0 p.m.
1.v.28 ...	72	1.0	4.0 p.m. 4.55 p.m.	6.ix.28 ...	19	5	8.20 a.m. 8.50 a.m.
14.v.28 ...	238	3.0	1.50 p.m. 3.40 p.m.	20.ix.28 ...	45	7	12.16 p.m. 12.48 p.m.
16.v.28 ...	120	4	6.05 a.m. 8.0 a.m.	22.ix.28 ...	13	15	7.29 a.m. 7.59 a.m.
27.v.28 ...	175	3	7.33 a.m. 8.48 a.m.	6.x.28 ...	96	17	2.20 p.m. 3.30 p.m.
29.v.28 ...	266	2	2.35 p.m. 4.35 p.m.	8.x.28	43	12	8.30 a.m. 9.05 a.m.
12.vi.28 ...	31	42	7.25 a.m. 7.55 a.m.	22.x.28 ...	17	12	8.0 a.m. 8.30 a.m.
14.vi.28 ...	320	9	12.49 p.m. 2.14 p.m.	24.x.28 ...	77	15	12.45 p.m. 1.47 p.m.
2.vii.28 ...	22	18	7.45 a.m. 8.15 a.m.	5.xi.28 ...	140	6	2.05 p.m. 3.30 p.m.
4.vii.28 ...	173	13	12.38 p.m. 1.43 p.m.	7.xi.28 ...	232	16	9.03 a.m. 11.12 a.m.
17.vii.28 ...	28	21	7.52 a.m. 8.22 a.m.	20.xi.28 ...	32	0	2.45 p.m. 3.15 p.m.
19.vii.28 ...	105	7	2.20 p.m. 3.30 p.m.	22.xi.28 ...	51	8	8.47 a.m. 9.34 a.m.
31.vii.28 ...	98	5	2.50 p.m. 4.0 p.m.	3.xii.28 ...	36	11	1.45 p.m. 2.15 p.m.
2.viii.28...	86	8	10.20 a.m. 11.12 a.m.	5.xii.28 ...	84	2	6.15 a.m. 7.25 a.m.
16.viii.28...	113	4	11.25 a.m. 12.15 p.m.				
18.viii.28...	125	7	10.30 a.m. 11.40 a.m.				

The female element of a fly community may appear in its true numbers under exceptional atmospheric conditions. In the middle of a fly-round that was carried out on 17.iv.28, a tremendous storm approached; the rain could be heard for some time before it arrived, and the wind was exceedingly strong and gusty; the female per cent. was rather high. The writer and his assistants had just entered a *Berlinia* wood noted for its low female sex ratio, which averaged 8 per cent. for the month in question. There was a torrential downpour lasting for about 50 minutes. The catchers stood under a tree and did not move about. In all they caught 33 fly, of which 51 per cent. were females; only two of these were freshly emerged. Despite the extreme heaviness of the rain, the fly were extremely lively and difficult to catch; however, they were very persistent. When the downpour gave way to steady rain, the females disappeared, and the fly-round was resumed; the *Berlinia* section yielded 37 fly, of which 8 per cent. only were females.

It has been noticed on other occasions, that mere steady rain does not augment the female activity; it would appear that only under such extreme aerial conditions as have been described does the female of *G. morsitans* appear to man in its true numbers.

The Vegetation Factor.

Brief Description of the Vegetation of Kikori.

The hills forming the escarpment are clothed in *Brachystegia microphylla*, which gives a good shade and retains its leaves longer than any of the other important communities. These woods are much favoured by fly, probably on account of the shade, and also on account of the admirable breeding sites formed by the outcropping slabs of rock.

At the foot of the escarpment one finds communities of *Berlinia globiflora*. This species loses its leaves earlier than *B. microphylla*, but it also produces good shade, owing to the shadows cast by the trunks, which grow in close stands. *G. morsitans* probably favours this community on account of the shade, and because of the abundance of fallen trees lying upon loamy soils, which is very suitable for the deposition of larvae.

Combretum zeyheri savannah usually succeeds the *Berlinia*. This species loses its green leaves very early in the year, but some dry foliage persists until the rains. A *Combretum* community is favourable to fly during the rains and the months following, but once its leaves have fallen, it becomes almost deserted by fly. *Combretum* savannah is not favourable to breeding; if the community is on "black cotton" soil, the surface is likely to be too water-logged in the rains, and too hard in the dry season, to permit of the successful pupation of extruded larvae. Even if the *Combretum* is on red alluvial soil, *G. morsitans* does not favour this type of vegetation as a breeding area, because the fallen trunks are of such small girth that they cannot afford shade conditions suitable for puparia.

Beyond the *Combretum* savannah one may find a second belt of *Berlinia*, *Acacia usambarensis*, or *A. campylocantha* wooding. The two species last named appear to favour the low-lying country with soil having a high water content.

Acacia usambarensis retains its leaves for a considerable period, and even after leaf-fall its large crown gives good shade conditions. Often there is an under-storey of *Combretum*. Fly favours this type of wooding. Should this community be growing upon a sandy soil, then its large fallen trunks form excellent breeding sites; however, should it occur upon stiff clay, then breeding does not occur, except within a rotten trunk containing much humus.

Acacia campylocantha prefers moister conditions and is often found on heavy, grey alluvial clay. It may occur in conjunction with *Acacia xanthophloea* (Fever Tree), bordering the Kikori stream or moist thickets. It loses its leaf according to the available water content of the soil. In damp sites there is no apparent period of leaflessness, as the new leaf gradually displaces the old. In drier localities complete leaf-fall occurs. The relation of tsetse to this community has been studied but little; however, it seems to be favourable to fly. Owing to the heavy clay soils upon which it usually grows, it is not suitable as a breeding habitat.

As will be seen from the map, a large area is covered by a belt of semi-thicket primarily composed of *Dalbergia melanoxylon*, *Combretum zeyheri*, *Commiphora* sp., and a few *Acacia spirocarpa*. This belt is near the edge of the "Great Mbuga;" it occurs on red alluvial soil and exists under relatively semi-arid conditions. It is suitable as a fly-habitat, but not for breeding, owing to the lack of logs and the hard clay soil. The eastern limit of this community is bounded by a fringe of *Acacia spirocarpa*, which opens on the large grassy steppe, known as the "Great Mbuga."

This open grass land, which is part of the Masai Steppe, is quite unsuited to *G. morsitans* and marks the eastern edge of the fly belt. The soil is heavy "black cotton" clay.

Acacia spirocarpa favours drier soils than either *A. campylocantha* or *A. usambarensis*, and hence is most abundant on the lower levels fringing the Masai Steppe.

North of the Kikori stream there is a large belt of this community, sloping down to the "mbuga." It retains its leaves for a long time and is favourable to fly. Should the soil be light, then these woods form possible breeding sites.

TABLE VII.
North-east Kikori Round 29.iii.28 to 29.iii.29.

Section number	Total fly caught	Length of section	F.B.100 Y.	Nature of section
I ...	28	735 yards	0.04	Cultivation
II ...	270	1,035 "	0.3	Native path: <u>Old cultivation</u>
XII ...	270	414 "	0.7	<u>Combretum savannah</u> <i>Acacia campylacantha</i> and <i>A. xanthophloea</i> bordering moist thicket near cultivation
III ...	1,641	1,977 "	0.8	Native path through <i>Combretum savannah</i>
XI ...	1,609	742 "	2.2	Impure <i>Combretum</i> containing <i>Commiphora</i> , <i>Parinarium</i> , <i>Vitex</i> , etc.
IV ...	3,759	1,554 "	2.4	<i>Combretum savannah</i>
VII ...	1,996	768 "	2.7	Native path: <u><i>B. microphylla</i> and <i>Ac. usambarensis</i></u>
VIII ...	861	292 "	3.1	<u><i>Combretum savannah</i></u> <i>Combretum savannah</i> on edge of <i>B. micro-</i> <i>phylla</i> wood
VI ...	1,942	519 "	3.7	<i>Combretum savannah</i>
V ...	5,784	1,434 "	4.0	<i>Acacia usambarensis</i>
X ...	4,261	960 "	4.4	<i>Brachystegia microphylla</i>
IX ...	8,141	1,390 "	5.9	<i>Brachystegia microphylla</i>
total ...	30,562	6 miles, 1,260 yards		

In the small "mbugas" that occur within the fly belt, one finds *Acacia seyal* (mis-called *Acacia verrugera* on the map) and the gall acacias, *A. formicarum* and *A. drepanolobium*. None of these species forms habitats suitable for permanent occupation by *G. morsitans*; they contain only a few wandering individuals that have left the surrounding woods in search of food. Large areas of these plant communities are almost fly-free.

Vegetation Distribution as compared with Fly Distribution.

A correlation between the type of vegetation and the density of the fly has been made by means of the F.B. 100 yards unit.

The following figures have been obtained by adding all the fly caught on each section for the year 29.iii.28 to 29.iii.29. By dividing these totals by the numbers of times each section was visited during the year, one obtains the average number of fly per visit for each section. This figure is then converted into fly per boy per 100 yards, by the formula.

$$\frac{\text{No. of fly} \times 100}{\text{No. of boys} \times \text{distance}} = \text{F.B. 100 Y.}$$

A figure is now available that will show what sections have been most favoured by fly during the year.

N.E. Kikori Round (Table VII).—The sections following native paths will be dealt with later. It is clear from these figures that the preference of *G. morsitans* for the different vegetation communities is as follows:—1st, *Brachystegia microphylla* wooding; 2nd, *Acacia usambarensis*; 3rd, *Combretum savannah*; 4th, *Acacia campylacantha* and *A. xanthophloea* near cultivation; and 5th, cultivated land.

It will be noticed that the fly preference for paths varies according to the attractiveness of the surrounding vegetation. The order of preference is as follows:—

- 1st. Path through *B. microphylla* and *A. usambarensis*
Combretum savannah.
- 2nd. Path through *Combretum* savannah.
old cultivation
- 3rd. Path through *Combretum* savannah.
- 4th. Path through cultivated land.

It is seen from the table that path concentrations do not exist, and that fly density along a path is lower than that of the surrounding bush. Compare Section III with IV, and Section VI with VII.

S.E. Kikori Round (Table VIII).—Path sections will be dealt with later. The preference of *G. morsitans* for the different vegetation communities is as follows:—1st, *Acacia usambarensis*; 2nd, *Berlinia* wooding with an occasional *B. microphylla*; 3rd, *Combretum* savannah; 4th, open "mbuga" with gall acacias and *Acacia seyal*; and 5th, cultivated land.

TABLE VIII.
South-east Kikori Round, 29.iii.28 to 29.iii.29.

Section number	Total fly caught	Length of section	F.B.100 Y.	Nature of section
I ...	59	1,100 yards	0.05	Cultivated land
II ...	1,008	1,140 "	1.0	Native path through <i>Cultivation</i> <i>Combretum</i> savannah
III ...	643	616 "	1.1	Native path through <i>B. microphylla</i> and <i>Berlinia</i> transition with <i>Combretum</i>
IX ...	2,265	1,962 "	1.2	Open "mbuga" with gall acacias and <i>Acacia seyal</i>
IV ...	4,317	2,352 "	1.9	Native path through <i>B. microphylla</i> and <i>Berlinia</i>
VI ...	2,869	1,104 "	2.6	<i>Combretum</i> savannah
V ...	1,756	680 "	2.6	<i>Berlinia</i> wooding with a few <i>B. microphylla</i>
VII ...	2,689	704 "	3.2	<i>Berlinia</i> wooding with a few <i>B. microphylla</i>
X ...	6,840	1,920 "	3.6	<i>Acacia usambarensis</i> with <i>Combretum</i> understorey
VIII ...	4,013	972 "	4.1	<i>Acacia usambarensis</i> with <i>Combretum</i> understorey
Totals ...	26,459	7 miles, 230 yards		

On this round *B. microphylla* is replaced by the less favoured *Berlinia* wooding, with the result that *Acacia usambarensis* heads the list.

Again, the fly preference for paths varies according to the attractiveness of the surrounding vegetation:—

- 1st. Native path through *B. microphylla* and *Berlinia* wooding.
- 2nd. Native path through *B. microphylla* and transition to *Combretum*.
Cultivation
- 3rd. Native path through *Combretum*.
- 4th. Cultivated land.

Here, also, path concentrations do not exist, and the fly density of the path is less than that of the surrounding bush. Compare Section IV with V.

S.E. Kandaga Round (six months, 7.iv.28 to 15.x.28).—For the sake of brevity the figures for the 21 sections will not be given in detail. The fly density of Kandaga is much lower than that of Kikori. On this round whose length is 11 miles, 1,382

yards, 6,997 fly were taken in six months. Vegetation communities represented by only one section on the Kandaga round, and unrepresented at Kikori, will be omitted; such sections would give untrustworthy results owing to the small amount of data available. Taking the average F.B. 100 Y figure for sections tapping the same vegetation types, one obtains the following order of fly preference (Table IX).

TABLE IX.

Order of preference	No. of representative sections	Average F.B. 100 Y.	Vegetation community
1st ...	2	1.30	<i>Berlinia</i>
2nd ...	3	1.29	<i>Combretum</i> savannah
3rd ...	2	0.92	<i>Acacia spirocarpa</i>
4th ...	1	0.20	Gall acacia (thickened with <i>A. senegal</i>)
5th ...	1	0.06	Open "mbuga" with thin gall acacia
6th ...	2	0.04	Cultivation

Again the preference for paths varies according to the surrounding vegetation, and here also no path concentrations exist. Kandaga is 20 miles from Kikori and has several different vegetation communities represented; yet one finds a distinct measure of agreement with the Kikori order of preference.

Conclusions.—1. The following is the order of fly preference, as given by the three fly-rounds:—

1st, *Brachystegia microphylla*; 2nd, *Acacia usambarensis*; 3rd, *Berlinia globiflora*; 4th, *Combretum* savannah; 5th, *Acacia spirocarpa*; 6th, *Acacia campylacantha* and *Acacia xanthophloea* community; 7th, gall acacias (thickened by *A. senegal* or *Commiphora*); 8th, open "mbuga," with a few gall acacias; and 9th, cultivation.

2. The fly density on native paths varies according to the attractiveness of the surrounding vegetation.

3. No path concentrations occur in this district.

TABLE X.

North-east Kikori Round, 29.iii.28 to 29.iii.29.

Order of female preference	Female percent.	Vegetational community	Details	Numbers of representative sections	Mean F.B. 100 Y.
1st ...	46	Cultivation (extensive)		I	0.04
2nd ...	18	Native paths (varying as the female preference for the surrounding vegetation)	18 per cent. path through cultivation	I	0.30
	to 10		15 per cent. path through <i>Combretum</i> savannah 10 per cent. path through <i>B. microphylla</i> • <i>Combretum</i> savannah	III VII	0.80 2.70
3rd ...	9 to 4	<i>Combretum</i> savannah (varying according to the visibility)	9.8 per cent. fairly thick stand	IV & VI	3.05
			4 per cent. very thick and impure stand	XI	
4th ...	2	<i>Brachystegia microphylla</i>		IX & X	5.15

TABLE XI.

South-east Kikori Round, 29.iii.28 to 29.iii.29.

Order of female preference	Female percent.	Vegetational community	Details	Numbers of representative sections	Mean F.B. 100 Y.
1st ...	46	Cultivation (extensive)		I	0.05
2nd ...	35	"Mbuga" (the greater the visibility the more attractive to females)	35 per cent. open "mbuga" of gall acacia type	IX	1.20
	to 24		24 per cent. "mbuga" with thin stand of <i>Combretum</i>	VI	2.60
3rd ...	19	Native paths (varying as the female preference for the surrounding vegetation)	19 per cent. Cultivation	II	1.0
	to		<i>Combretum</i>	III	1.10
	11		16 per cent. <i>Combretum</i> transition to <i>Berlinia</i> and <i>B. microphylla</i>	IV	1.90
4th ...	9	<i>Berlinia</i> wood-ing	9 per cent.	V	2.60
	to 8		8 per cent.	VII	3.20

TABLE XII.

South-east Kandaga Round, 7.iv.28 to 15.iv.28.

Order of female preference	Female percent.	Vegetational community	Examples	Numbers of representative sections	Mean F.B. 100 Y.
1st ...	44	"Mbuga" (the greater the visibility the more attractive to females)	44 per cent. open "mbuga" and thin gall Acacias.	XV	0.06
	to 39		39 per cent. open "mbuga" and <i>Acacia spirocarpa</i>	XIII	0.97
2nd ...	33	Gall acacias (thickened with <i>Acacia senegal</i>)		XIV	0.20
3rd ...	19	Thick <i>Combretum</i> savannah Paths Clearings and small-scale cultivation	19 per cent.	XVII, VIII, XII V, VI, III I, XX, XXI, II	0.68
	to 18		18.5 per cent. 18 per cent.		
4th ...	15	Pure <i>Acacia spirocarpa</i> <i>Berlinia</i>	15 per cent.	XIX	1.31
			15 per cent.	VII, X	
5th ...	11	Thicket		XI	1.06

*Vegetational Distribution, as compared with the Distribution of the Sexes of
Glossina morsitans.*

The accompanying tables show the variations in female per cent. according to the vegetation (Tables X and XI). The female per cent. is obtained from the total number of fly caught upon the section during the year 29.iii.28 to 29.iii.29.

The following list has been made after examination of each table; it is intended to show in what types of vegetation females will show themselves, and in what communities females remain inactive.

Females active. Cultivation (extensive).
 " Mbuga " (gall acacias or thin *Combretum* type).
 Paths.
 Combretum savannah.
 Berlinia wooding.

Females inactive. *Brachystegia microphylla*.

It is to be noted that *Acacia usambarensis* has been left out of the tables for the following reasons:—Should this species exist on the edge of an open "mbuga" and have poor grass and good visibility, it may be an area of female activity—thus there may be 23 per cent. females in the catch. Should *A. usambarensis* exist apart from an open "mbuga" and have an under-storey of thick *Combretum* with tall grass, giving poor visibility, it may be an area of female inactivity.

The Kandaga female per cent. figures are given in the accompanying table (Table XII). Owing to the low fly density, and shorter period of readings, these results cannot be relied upon to the same extent as the figures for Kikori. They do show, however, that more females come to man in open country than in thickly wooded country.

The following table (Table XIII) gives the female per cent. of the area tapped by each round during a stated period; it also gives some idea of the size of the figures upon which the previous tables were based.

TABLE XIII.

Kikori N.E. Round.				Kikori S.E. Round.				Kandaga S.E. Round.			
Total fly	No. of females	Female per cent.	Period	Total fly	No. of females	Female per cent.	Period	Total fly	No. of females	Female per cent.	Period
30,562	1,939	6	12 mths.	26,459	4,055	15	12 mths.	6,997	1,367	19.5	6 mths.

It is noteworthy that the N.E. Kikori round, which does not tap a single "mbuga" or open space, has the lowest female per cent.; the Kandaga round, which taps much open country, has the highest female per cent.

The areas of female inactivity are definitely marked off from those of activity by vegetation boundaries. One may find a regular, sharply defined alternation between apparent male and female areas, according to the vegetation distribution; or one may get a gentle transition from an area of female inactivity to one of activity, according to the presence or absence of a transition stage in the vegetation.

Below are two examples, taken from the two series of succeeding fly-round sections (Table XIV). The percentages have been obtained from data collected over the period of a year.

TABLE XIV.

Ex. 1. S.E. Kikori Round.

Ex. 2. S.E. Kandaga Round.

No. of section	Vegetational Community	Female per cent.	No. of section	Vegetational Community	Female per cent.
V	<i>Berlinia</i> wood	8	XI	Thicket	11
VI	Mbuga of thin <i>Combretum</i>	24	XII	<i>Combretum</i> (thick stand)	15
VII	<i>Berlinia</i> wood	9	XIII	Open mbuga with a few <i>Ac. spirocarpa</i>	39
VIII	Thin <i>Ac. usambarensis</i>	23	XIV	Thick gall acacia	33
IX	Open mbuga, gall acacia type	35	XV	Open mbuga, very thin gall acacias	44

Ex. 1. Sections V to VI to VII are examples of sharply defined alternations between apparent male and female areas. Sections VII to VIII to IX illustrate a gentle transition between the apparent male area in the *Berlinia*, through the intermediate *Acacia usambarensis* zone, to the apparent female area in the open "mbuga."

Ex. 2. Section XII acts as a transitional belt between the apparent male area XI, and the apparent female area XIII. Sections XIII, XIV, and XV show that there may be variations in the female per cent. of an apparent female area, just as one gets variations in a male area.

Discussion on sex activity.—From the evidence adduced it is indicated that:—

1. Open "mbuga" country is favourable to female activity, thus giving an impression of an area rich in female fly.

2. Well wooded country, having a poor visibility, such as *Berlinia*, *Brachystegia microphylla*, and thickets, is not favourable to female activity, and hence gives an impression of being an area rich in males.

3. Broadly speaking, the greater the fly density, the lower the female per cent. The corollary also holds good.

4. Apparent male and female areas depend for their existence upon the vegetational distribution. Should a vegetational transition exist between thickly wooded and open country, then there will be a transitional belt between the area of female inactivity and of female activity. If there is no transition, then the apparent male and female areas will be sharply demarcated.

From the foregoing results there are clearly two possibilities:—(a) That there are definite male and female habitats. In other words, that in *Berlinia* wooding hardly any females exist, whereas there is a definite female population in an "mbuga." Should this be the case, one would conclude from the figures that the females of *G. morsitans* are much fewer than the males.

(b) That females are just as numerous as males, even in thicket or *Berlinia* wooding, but that, in such habitats they are inactive, and hence do not come to the net. On the other hand, in open "mbuga" females are active and appear in numbers approaching the true sex proportion.

Much indirect evidence has been obtained to show that true male and female areas do not exist, and that the varying disparity in the apparent proportions of the sexes is explicable by their difference in activity.

It has been found from the breeding of large numbers of puparia, collected from the bush, that the sexes emerge in approximately equal numbers. Since one catches very small numbers of females in the well-wooded areas, and since one very rarely takes more than 50 per cent. females in the favourable open country, there must be large numbers for which one cannot account. This can only be explained by the supposition that the females are hiding, either in the hot, open "mbugas," or in the shady thickets, *Berlinia* or *B. microphylla* woods. No evidence can be found to show that the females remain quiescent in the shadeless "mbugas," but there is some to show that they frequent the apparent male areas, even though very few ever come to the net.

The *Berlinia* and *Brachystegia* woods, which form the apparent male areas, are the great breeding centres of the district. Far more puparia are taken from such areas than anywhere else. Obviously, these puparia could not occur in the male areas unless there were females to extrude the larvae. No puparia can be found in the hard "black cotton" soils of the "mbugas." The extent of the female inactivity can be gauged by the following example:—

Larger numbers of puparia can be found, under the rocks, in the *Brachystegia* wood of Section IX, N.E. Kikori Round, than anywhere else in the district. This beat has the greatest fly density of any section of the three fly-rounds, and yet it has the lowest female per cent. In one year, 8,141 fly were caught here, and only 2 per cent were females. Only on one occasion has the writer seen the inactive female element of an apparent male area appear in its true numbers. This was the day when a catch of 51 per cent. females was taken in a *Berlinia* wood during a torrential downpour.

It is suggested that equal numbers of males and females exist in these areas of female inactivity. Further, that individuals of both sexes, when hungry, fly out into the open "mbuga" in search of food, and that, when fed, they seek the nearest shady wood. The female remains inactive until she is ready for another meal; but having partially digested its food, the male flies about in search of females, or is attracted by the movement of any passing object, upon which it may settle, even though it does not attempt to probe.

The inactivity of the female, after a meal, may be because this sex is naturally indisposed to be active for a long period after food, or it may be due to a wish to avoid the violent attentions of the male (*vide* Lamborn, 1915). In favour of this latter explanation, it should be remembered that there is a tendency for the female inactivity to vary according to the density of the fly.

The above suggestions are strengthened by the writer's observations that fly caught in open country are almost invariably hungry, and come with the definite purpose of feeding; whereas the fly taken in wooded male areas are often filled with only partially digested blood, and make no efforts to probe.

Again, the bulk of the young fly must have originated from the breeding sites in the male areas; yet most of them are caught in the open "mbugas." As young fly are considered to be primarily engaged in searching for their first meal of blood, it is indicative that they should make for these open places.

It is believed that the male areas form the true fly habitat, and that the open country is used as a feeding ground by hungry individuals of both sexes. Since it is likely that, at any given time, there will be about equal numbers of each sex wanting a meal, it is only to be expected that one would catch a large number of females in these hunting grounds. The open "mbugas" have a much smaller fly density than

the surrounding woods, which is to be expected, as it is hardly likely that all the fly of a community will be wanting food at the same time.

Using Lamborn's hypothesis, owing to thin fly in the feeding grounds, the females will be able to search for game without being constantly molested by the males, and hence will appear to man in these areas. The above suggestion, woven around facts, is an effort to explain some of the curious results obtained; however, the writer is not dogmatic upon the matter, and realises that there may be other explanations.

TABLE XV.

KANDAGA SOUTH-EAST ROUND.

Date	SECTION VIII. <i>Combretum</i> savannah		SECTION IX. Orchard Bush (many small thickets)		SECTION X. Thick <i>Berlinia</i> Wood	
	Total fly per period	Leaf-fall	Total fly per period	Leaf-fall	Total fly per period	Leaf-fall
24.iv.28	36	<i>Combretum</i> green, grass turning	46	All species green	89	All species green
8.v.28	31	<i>Combretum</i> turning	38	Upper grass stems turned	90	—
Rains ended 23.v.28	61	Grass dry, <i>Combretum</i> turning	46	<i>Lannea humilis</i> , <i>Commiphora</i> and a few <i>Berlinia</i> turning, grass nearly dry	95	Smaller <i>Berlinia</i> turning
8.vi.28	29	Large <i>Combretum</i> yellowing fast, but some small ones still green	43	<i>Lannea humilis</i> , <i>Commiphora</i> and some <i>Berlinia</i> leafless, grass dry	65	Smaller <i>Berlinia</i> leafless, large trees green, <i>Combretum</i> turning
22.vi.28	40	A few <i>Combretum</i> leafless, others yellowing fast	53	<i>Berlinia</i> leafless or green, <i>Combretum</i> leafless or turning	77	Almost leafless
9.vii.28	37	Almost leafless	45	<i>Berlinia</i> leafless, some <i>Combretum</i> still yellow, <i>Dalbergia</i> turning	62	Almost leafless
25.vii.28	24	Almost leafless	37	Trees leafless	123	Leafless
9.viii.28	14	Leafless	82	—	116	—
31.viii.28	13	—	34	—	117	—
15.ix.28	14	—	43	—	97	—
28.ix.28	16	—	44	—	107	—
14.x.28	12	—	38	—	146	—

The Effect of Leaf-fall upon G. morsitans.

Three sections have been taken to illustrate the effects of leaf-fall (Table XV). Section VIII of the S.E. Kandaga Round taps *Combretum* savannah, and section X thick *Berlinia*. Section IX is the transition zone of orchard bush. During the rains, all three types give good shade conditions. In the dry season section VIII is open and very hot; owing to the presence of small thickets, section IX yields fairly good shade; and section X gives good cover owing to the thickness of the *Berlinia* stand.

From the accompanying table, it will be seen that there were quite a number of fly frequenting section VIII, during the late rains and after, until the *Combretum* was almost leafless. From then fly were very scarce in the area. The transition IX preserved a steady density during both the late rains and the dry season. The thick *Berlinia* of X yielded rather a low density during the late rains and after ; it was not until section VIII was losing its fly population, owing to the leaflessness of the *Combretum*, that fly became really numerous in the *Berlinia*. The fly density of X remained at a high level for the remainder of the dry season.

It would seem that there must have been a movement of fly from the savannah, through the transition, into the *Berlinia*. Possibly the temporary rise in density registered in section IX for the period 9.viii.28 was due to the catching of a body of fly that was retreating through the transition towards the *Berlinia*.

These figures seem to indicate that fly evacuate their wet season haunts, as soon as these become leafless, and frequent those woods where the vegetation, though leafless, can give good shade conditions owing to the shadows cast by thick stands of trees having large crowns.

In the Western Fly Belt, Kondoa-Irangi, in 1927, the writer noticed that during the height of the dry season the fly were centred in the large *Berlinia* woods, and that they were scarce in the " mbugas " ; once the rains had broken and the trees were in new leaf, fly became much scarcer in the *Berlinia* and more numerous in the open country.

In 1928, on the Kikori South East Round, the fly density decreased in the thin *Combretum* of section VI once the leaves had begun to fall ; simultaneously, the density in the *Berlinia* (section VII) increased. Unfortunately, the fires swept through the area in late September and prevented these observations from being completed.

Thus it would seem that, during the period when the vegetation is in leaf, the fly is scattered throughout the open *Combretum* savannah country. Once the vegetation is leafless, the fly evacuate the *Combretum* communities and tend to settle in the *Berlinia* woods. It is noteworthy that *Berlinia* can, in the absence of non-deciduous vegetation, be utilised as a dry season habitat. The point is significant, since it suggests that in those fly belts where there is much *Berlinia* wooding, there will be no small dry season concentrations from which the fly can be exterminated. According to Johnson,* in Nigeria *G. morsitans* concentrates in the riverine vegetation, which, owing to its limited distribution, can be economically cleared.

The Game Factor.

The distribution of the game has been studied in great detail, but it will suffice to describe it here in bare outline.

At all seasons of the year there is game in the district, but in some months it is very abundant. At no season is game so scarce that there is fly starvation. When water is plentiful, game is comparatively scarce ; then zebra and Coke's hartebeest are the commonest species. In times of drought the numbers of zebra and hartebeest greatly increase, and in addition to the normal fauna both Grant's and Thompson's gazelles, wildebeest, oryx and lions come in from the Masai Steppe. When the game come in for water, they concentrate in the country tapped by the S.E. fly-round, but the N.E. round is not appreciably affected. The fauna of the hills, composed of animals such as greater kudu, roan antelope and zebra, is much more constant than the fauna of the plains and is not subjected to game concentrations.

* This statement was made by Dr. W. B. Johnson in conversation.

The Distribution of the Non-migratory Kikori Game.

For convenience, the district may be divided into the three following areas:—

1. The country north of the Kikori Stream.
2. The environs of the Kikori Stream.
3. The country south of the Kikori Stream.

1. *The country north of the Kikori Stream.*

(a) The country west of the Kikori-Galapo path. This area is mainly composed of hills clothed in *Brachystegia microphylla*, with intervening valleys which support *Berlinia globiflora*.

Greater kudu and zebra are the commonest species of game; giraffe and water-buck are seen occasionally. No game movements take place in these hills; well-known herds and individuals will be seen in roughly the same haunts for months at a time. The constant food supply, together with ideal rock breeding sites and good shade conditions, probably account for the infestation of this area by *G. morsitans*. The greater kudu are centred in the west end of the valley (Map Square 4.B.) that lies N.W. of Tree 9. During the dry season, they lie up during the heat of the day in the evergreen bush that borders a dry stream-bed, which runs down this valley.

(b) The country east of the Kikori-Galapo path. The *Combretum* savannah (M.S.5.F) and the *Acacia usambarensis* wood (M.S.3.G) are much frequented by greater kudu. As many as 15 have been seen together. A few zebra and wart-hog also inhabit this country. During the rains rhinoceros may sometimes be seen in the *Acacia usambarensis*. The country lying east of this area, and extending to the edge of the "Great Mbuga," is occupied by rhinoceros, which lie up in the small moist thickets during the day time and wander in the *Acacia campylacantha* and *A. usambarensis* woods during the night and early morning. A few zebra may sometimes be seen in this country, but owing to the height of the rank grass it is not favoured by the smaller species of game.

2. *The environs of the Kikori Stream.*

Each bank is lined with *Acacia xanthophloea* and *A. campylacantha*. The understorey consists of shrubberies of evergreen vegetation. Generally speaking, the country on each side of the stream is park land composed of *Acacia usambarensis* and *A. campylacantha* growing on grey alluvial clay. The most characteristic species of game in this belt is the rhinoceros. Owing to the numerous wallows and leafy thickets available at the end of the rains, this species is spread all over the country north of the stream. Later on, when the wallows are dry and the thickets are losing their leaves, the rhinoceros concentrate round the Kikori Stream, where there is much cover, either in the long grass of the river-bed or in the evergreen shrubberies.

A few zebra, giraffe, and hartebeest permanently frequent this area.

3. *The country south of the Kikori Stream.*

(a) The country west of the Kikori-Kissese road. This area is clothed with *Brachystegia-Berlinia* wooding, and is very similar to the country west of the Kikori-Galapo path; however, the greater kudu is replaced by roan antelope. There are several permanent herds of zebra and a family of three lions; the latter are centred round the dry river-bed (M.S.15.D). Fly is very dense among these hills.

(b) The country east of the Kikori-Kissese road. This area is characterised by its zebra, hartebeest and giraffe. Impala, reed-buck, and roan also occur. Much of the country is covered with open bush and short grass. There are also several *Berlinia* woods, which afford shade during the heat of the day. Great game

movements occur in this area. The fear of lions probably causes the visiting game to choose this open country, in preference to the well-wooded areas with long grass.

East of this open bush there is the large *Dalbergia-Commiphora-Combretum* wood, which in many parts is semi-thicket. This area is frequented by impala. During 1928 a family of three rhinoceros lived in the denser parts of the wood. Unfortunately, they were all shot before the district was made into a game reserve.

The Migratory Game and their Concentrations.

Four game movements occurred in the year 29.iii.28 to 29.iii.29.

1. *The July game concentrations round the pools (M.S.15.F.).*—This was the smallest of the four movements. When the drinking holes on the edge of the "Great Mbuga" dried up, large herds of zebra and hartebeest concentrated in the *Combretum* "mbuga" in which these pools are situated. Prior to the arrival of the game, there was no concentration of fly near the water-holes, but shortly before the pools dried and for some time afterwards there was great density of fly in their vicinity.

While the game was in the "mbuga," the fly density between Trees 5 and 6 was very high. Once the game had dispersed, there was a great drop in the number of fly taken. The same type of game movement took place in 1929, but, owing to the poor rains, it started earlier.

The following table shows the effect upon the fly density of Section V to VI, which lies in the same *Combretum* "mbuga" as the pools, but $1\frac{1}{4}$ miles further south (Table XVI). The effect upon the tsetse of the 1929 movement is discussed later under "Fly Painting Experiments."

TABLE XVI.

Section VI. S.E. Kikori Round, 1928			Section VI. S.E. Kikori Round, 1929		
Date	Fly total per period	Remarks	Date	Fly total per period	Remarks
13.vi.28	187	Water in holes, game concentrated	7.v.29	112	Water in holes
3.vii.28	167	Water in holes, game concentrated	20.v.29	92	Game started concentrating 27.v.29
18.vii.28	160	Water-holes just dry	3.vi.29	190	
1.viii.28	67	Game completely disappeared	15.vi.29	164	Only mud in holes on 17.vi.29; a few zebra still in "mbuga"
17.viii.28	79	Game, completely disappeared	26.vi.29	100	
5.ix.29	49	Game completely disappeared	11.vii.29	80	—

2. *The September-October Game Concentration upon the banks of the Kikori Stream.*—During this period large herds of game were following the stream as it dried towards its source. A large herd of over a hundred wildebeest came in from Misoui, which lies 20 miles N.E. of Kikori in the Masai Steppe, having been driven in owing to the drying up of the Misoui water. At this time the Kikori Stream only reached as far as M.S.9.L.

Every morning the wildebeest would drink, and then graze as far as the *Acacia campylacantha* wood (M.S.11.L), where they rested during the heat of the day. At about 4 p.m. they would journey out, in single file, to the "Great Mbuga," where they spent the night. The probable reason for this was a desire to be in open, short grass country during the night, as several "troops" of lions had followed them in and had made their headquarters in the thickets near the stream. Many zebra also took part in the movement. Fly appeared to have concentrated at the water in large numbers, but no figures are available, as this area is not tapped by a fly-round.

3. *The mid-September to late November Game Concentration at the pools in Nimpara's Stream* (M.S.13.G).—The game concentrated near the path which joins Trees 9 and 10, because of its proximity to water. Large herds of zebra and hartebeest arrived in the district. Grant's gazelle, which are never seen nearer than the "Great Mbuga" except in times of drought, came right in; probably they were attracted by better grazing. For a month and a half herds of game were drinking within fifty yards of the fly-round path. During this period the fly density of the section was comparatively low. The early rains broke on 29th October, when 2 inches fell in the night. Immediately the great assembly of game broke up, and two days later only a few zebra and hartebeest remained. It was not until 6th November, when the game had completely dispersed, that the fly density was found to have increased tremendously. For a fortnight after the downpour there was no appreciable fall of rain. The young grass shrivelled, and the temporary pools in the "Great Mbuga" dried. Once more herds of zebra and hartebeest came in, and drank from the Nimpara's Stream. The fly density fell to its previously low level. By 25th November the water in the pools had dried; the game started to leave the area, and took to drinking from the Kikori Stream. The fly density started to rise.

The following table demonstrates this curious series of fluctuations (Table XVII). For comparison, some figures illustrating the effect upon fly of a concentration of men are also given; this will be dealt with later.

TABLE XVII.

Concentration of Game			Concentration of Men		
Section X. S.E. Kikori Round			Section IV. S.E. Kikori Round		
Date	Total Fly per period	Remarks	Date	Total Fly per period	Remarks
5.ix.28	132	Game concentrated	13.vi.28	150	Normal
21.ix.28	58	Game concentrated	3.vii.28	23	Road gang working
7.x.28	139	Game concentrated	18.vii.28	199	Normal
23.x.28	94	Game concentrated			
6.xi.28	372	Game dispersed			
21.xi.28	83	Game returned			
25.xi.28	—	Pools drying			
4.xii.28	120	Game dispersing			
17.xii.28	332	Game dispersed			

Note.—Rains broke 29.x.1928.

Thus, in this movement, the density did not rise until the game had left, whereas in the first movement described, the fly were dense while the game was concentrated, and much scarcer when the game had gone. Clearly the actual results are contradictory; however, it is considered to be an important point that in the first case the figures were obtained at a distance of $1\frac{1}{4}$ miles from the water-holes, whereas in this instance they were obtained from a path running parallel to the stream, and only 50 yards from it. In one case the fringe of the game movement was investigated, whereas in the other the core of the concentration was studied.

There are two possible explanations of the absence of fly from the core of the concentration :—

(a) That the fly were really present in great numbers, but that they were too busy feeding on the game to be attracted by the human catchers.

(b) That this is a parallel instance to the well-known and as yet unexplained fact that the arrival of a large gang of labour in a fly belt will cause most of the fly to disappear. As soon as the natives have gone, the fly return.

4. *The mid-February and March Concentrations in the country S. of Nimpara's Stream.*—This was the largest game concentration that, as yet, has been experienced. It occurred during the short dry season, when the maximum shade temperature reached 105° F. and a 12 per cent. humidity was recorded. The Kikori River had dried to well within the first cultivation, and so the game preferred the two pools at the source of Nimpara's Stream. By 14th February the wildebeest had returned, drinking in the morning and evening and spending the rest of the day in the small "mbuga" (M.S.14.H). Herds of zebra, hartebeest, and Grant's gazelle also appeared. Between 27th February and 5th March there were occasional showers, after each of which the wildebeest became restless and left for the "Great Mbuga," but by the next day lack of water had forced them back to their old haunts. On 5th March there was some rain, and from then onwards the game started to disperse.

This game movement was of particular interest because these herds of animals were centred in the heart of the S.E. round. Thus, the various sections did not pass through the core of the game concentration, as in the last case; instead, they skirted the outer fringe, as in the first game movement described. The fly density rose as the game concentrated, until it reached a maximum just after the game started to disperse; then it fell extremely rapidly. This effect upon the fly was identical with that illustrated by section VI, when the game were centred a mile away, near the water-holes in the *Combretum* "mbuga"; however, this last movement was on an infinitely larger scale, and instead of affecting only one section of the round, affected every part of it.

The table that follows indicates the fluctuations in the fly density of the S.E. round that were caused by a Game Concentration.

TABLE XVIII.

Date	South-East Kikori Round.		
	Total fly caught per period		Remarks
14.ii.29 ...	1,195	... ..	Game have just concentrated
26.ii.29 ...	1,424	... ..	Game concentrated
5.iii.29 ...	—		Dispersion started
12.iii.29 ...	1,837	... ..	Game dispersing
28.iii.29 ...	942	... ..	Game dispersed
9.iv.29 ...	911	... ..	Game dispersed

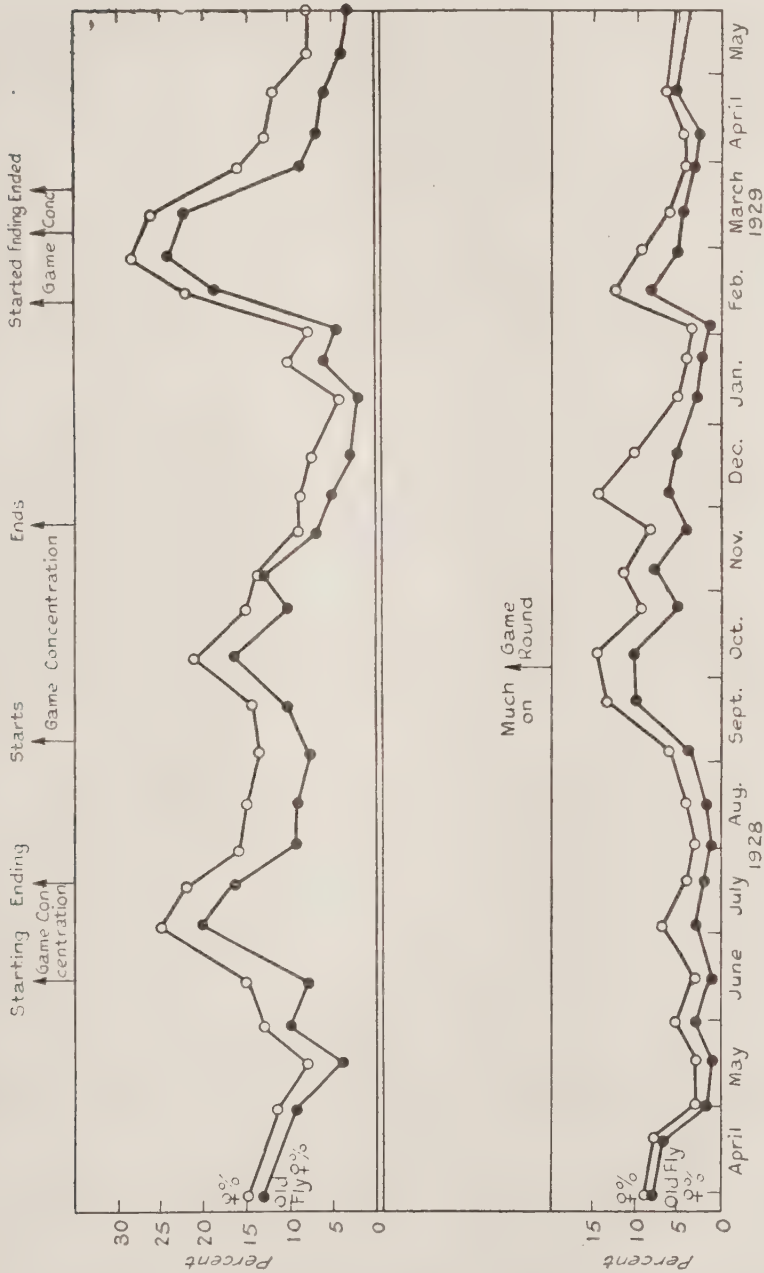


Fig. 8. Effect of game concentration upon female percentage: right, S.E. Kikori Round; left, N.E. Kikori Round.

The effect of Game Concentrations upon the Female percent. of a Fly Community.

In each of the three game movements that affected the S.E. Kikori round there has been a noticeable increase in the female per cent., and also in the percentage of females among old fly. This latter figure is obtained by subtracting the numbers of freshly emerged fly from the total catch and finding the female percentage of the old fly left. When wishing to make deductions upon the difference in female activity, it is useful to be able to ignore the emergence factor.

The accompanying graph shows the female percent. and old fly female percent. curves for both N.E. and S.E. rounds (fig. 8). It is evident that on the S.E. round a game movement distinctly affects the female percentages, whereas on the N.E. round, where the game concentrations of the other side are hardly noticed, one gets a mere reflection of these effects. It is of interest that the curves of the female percent. and old fly female percent. follow each other so closely. From this graph it is considered that the arrival of much game in an area causes an increase in the activity of the females.

Summary.

1. Only large game movements produce noticeable effects upon the fly community.
2. The fauna of the hills is not subjected to game concentration.
3. The country included in the N.E. Kikori round is not subjected to large game movements, as is the S.E. round.
4. A concentration of game appears to cause a considerable increase in fly density in the surrounding country; when the game have dispersed the density drops.
5. In the small area of country forming the core of the concentration fly appear to be very scarce while the game are present. When the game have left the density greatly increases.
6. The arrival of much game in an area causes an increase in the activity of the females.

III. INVESTIGATIONS IN THE INSECTARY.

The insectary work was not started until March 1929, and a combination of lack of time and unexpected difficulties has prevented the attainment of any important results; however, a description of the aims in view and difficulties encountered may be of interest.

An insectary has been built of dimensions 18 by 12 by 7 feet. The wire netting is lined with gauze, which prevents battering but does not reduce the light. The house is divided into two rooms—one only three feet in width—connected with each other by a door. On leaving the main room, the observer shuts the door and, standing in the small chamber, catches any fly that have followed him. These are returned by means of a sliding panel. The main apartment is provided with decaying logs and outcropping slabs of rock, forming what are considered ideal breeding sites. In addition two small shrubs have been planted. Shade is afforded by overhead and lateral screens.

Large numbers of puparia were collected from many localities in the field and were kept in the laboratory in glass tubes, stoppered with a plug of cotton-wool. As the fly emerged, their sexes were noted and they were liberated in the insectary. By this means information was obtained concerning the natural sex proportions and the percentage of parasitised puparia. In addition, the original tsetse-parasite ratio of the insect-house stock was known. The fly in this artificial colony were fed upon sheep.

In order to study *Glossina morsitans* at close quarters, clearly the first essential was to start a thriving colony of the fly within the insectary. This proved unexpectedly difficult. Frequently the fly have been seen to copulate, but females never become pregnant. Up to the present date not a single puparium or gravid female has been found within the insect house.

Mr. C. F. M. Swynnerton suggested that possibly sheep's blood was not conducive to breeding; this, indeed, has been the experience of other workers too. Accordingly a calf was procured, but it is too soon to decide whether or not breeding has started.

Conceivably the proffered breeding sites are unsuitable. The writer does not seriously consider this possibility, because he has found that under such extreme artificial conditions as tubes kept in the laboratory, fertilised females will become pregnant and extrude their larvae upon the bare glass. In the laboratory 1,040 fly have emerged from puparia collected in the bush. Among these 53 per cent. were females; 23 per cent. of the puparia collected failed to emerge.

As already stated, all the fly that emerged in the laboratory were liberated in the insect house; hence, the colony was composed of about equal numbers of the sexes. The writer suggests that the failure of the females to become pregnant was due to the impossibility of their finding concealment from the males when kept in such cramped quarters. Lamborn has put forward the idea that abortion is caused among gravid females by the persecution that they suffer from the males. He explains female inactivity as being due to their desire to hide from the opposite sex (Lamborn 1915). It has been decided to build a second insectary and to stock this with fertilised females only.

It is also desired to stock an insectary with *G. morsitans* and *Thyridanthrax abruptus*, Lw., a parasitic Bombyliid fly, in the same proportions as they occur in the field. This has been done, but owing to the failure of the tsetse to breed, the parasite has been unable to lay its eggs within the puparia of the fly. Once a thriving colony of *G. morsitans* has been started, it is hoped that the parasite will find itself in an ideal situation with abundant puparia available. From time to time samples of the tsetse puparia will be removed and bred out in the laboratory; a comparison between the percentage of parasitism for these puparia with the percentage already obtained from puparia collected from the field will show whether a rise has occurred in the insectary.

Should *T. abruptus* prove of economic importance, one might be able to produce large numbers of infested puparia under artificial conditions. It is quite realised that great difficulties are bound to present themselves, and that the aims in view may prove impracticable. Out of 764 emergences from puparia, 9.7 per cent. yielded *T. abruptus*; this is considered to be encouragingly high. This Bombyliid spends a comparatively long time within the puparium of *G. morsitans*. The bulk of the parasites do not emerge until some weeks after the last tsetse.

In this work one does not know when the tsetse puparium was parasitised by the female *Thyridanthrax*, so that one is ignorant of the exact length of the life-cycle. One can get a rough idea by considering the longest periods between the date of the collection of the puparia and the date of emergences; presumably the last fly to emerge came from those puparia that were youngest on the day of collection. Out of the 1,040 fly that were bred out, several were in the laboratory 51 days before they emerged. Out of the 93 parasites that were bred out, the maximum period was 197 days.

The parasite occurs throughout the Eastern Fly Belt and is to be taken from all types of breeding sites; however, the highest numbers have come from puparia found under *Acacia usambarensis* logs. Under one such log 92 puparia were collected, and they yielded 21 per cent. of *T. abruptus*.

The Bombyliid has often been seen in nature, sunning itself on paths. In captivity the insect will feed upon split sugar-cane, flowers, etc.

The whole of this investigation is still in a most elementary stage.

IV. EXPERIMENTS WITH MARKED FLIES.

The Fly Community frequenting certain Water-holes.

The water-holes (Map Square 15.F.) are situated in an "mbuga" composed of *Combretum-Terminalia* savannah, with a few small thickets. The wooding forms a poorly stocked stand, which gives a visibility of 100 to 200 yards, the grass being sparse and poor. The southern, eastern and western limits of the area are bounded by *Berlinia* wooding. The fly population of this "mbuga" is recruited from these bordering woods, where much breeding takes place; breeding is rendered impossible within the "mbuga," because of the "black cotton" soil, inundated during the rains, hard-baked during the drought.

The surrounding *Berlinia* woods support a fairly dense fly population, characterised by the usual high male percentage. The "mbuga" itself supports a comparatively high fly density, from the commencement of the early rains at the end of October until the middle of August, when lack of shade appears to render this country unfavourable to tsetse (*vide* Leaf-Fall, p. 233). The fly population of the "mbuga" is characterised by the high female percentage and the large number of freshly emerged fly.

At the northern end of this savannah country there are some water-holes consisting of a series of isolated pools that probably were once linked together to form a stream. Of these pools, the last two are the only ones of importance; the rest dry very rapidly after the last fall of rain. These two are not more than fifty yards apart; one has a clump of thorny shrubs on the bank, the other has a solitary large tree. In the investigation the two pools were treated separately, but since results show that their fly populations are similar, for sake of brevity it has been decided to treat them as one.

Since May 1928 these pools have been under constant observation, but it was not until February 1929 that intensive work was started. Prior to this recent work, the summary of information obtained was as follows:—

1. During periods of much rain there is no game concentration around these pools, owing to the large number of available water-holes in the neighbourhood. At this time they do not support an apparent fly concentration.

2. At the end of the rains the other holes rapidly lose all their water, and game concentrate around these "mbuga" pools. The following results were noticed in their fly population:—

- (a) Fly appeared to be hungry and attacked with vigour.
- (b) Fly appeared to be exceedingly numerous around the water-holes.
- (c) Sample catches showed that the female and freshly emerged fly percentages were very high.

3. Seven or eight weeks after the rains the pools dried and the game at once left the "mbuga." The dense fly remained around the pools, and continued to show the same characteristics; however, now they seemed to be starving, and attacked with such violence that it was painful to stay near the water.

4. Three weeks after the desiccation of the pools, the fly started to disperse; within a week the apparent concentration had collapsed. From these observations it was believed that:—

- (a) The regular visits of game to these pools had brought into being a concentration of fly that waited around the water until the game should come and drink.
- (b) That this concentration might consist of a "female crowd."
- (c) That when the water dried and the game left, the fly were stranded at the pools, and were waiting there for the daily visits of the herds of game; since none arrived, the fly were hungry and hence attacked the writer with unusual persistence.
- (d) That eventually the concentration dispersed, either because many of the fly died from starvation, or because they broke away from whatever was the attractive force that held them to the pools, and went off in search of food.

First Investigation.

Experiments were started twelve days after the game had left, and the pools were dry. They were designed to prove:—

1. Whether a fly concentration existed around the water-holes, *i.e.*, whether one would not eventually attract as large a number of fly as could be caught by the pools, if one were to remain long enough in any site in the "mbuga."
2. Whether the female percent. was really greater around the pools than in the rest of the "mbuga," *i.e.*, Was this a female centre?
3. Whether it was correct to assume that the individuals forming the alleged concentration had been there since the game departed.

Experiment 1.—In a part of the "mbuga," one mile south of the water-holes, widely separated sites were chosen; in each the fly were caught out, so as to yield the maximum density obtainable at each point. These figures were compared with the density of fly at one of the two pools. In each case the fly were marked and then liberated. Table XIX gives typical figures.

TABLE XIX.

Total fly caught on each "mbuga" site	Total fly caught round each water-hole
11	213
8	154
26	71
3	84
4	96
18	43

It is seen that the maximum density of fly obtained from one site in the "mbuga" was 26, as compared with a maximum for one hole of 213. There can be no doubt that a concentration of fly exists around the pools. The variability in the numbers of a catch in the "mbuga" was probably due to the visibility of the site selected. The decrease in fly density at the water-holes was due to the gradual disbanding of the concentration.

Experiment 2.—The percentages of the individuals forming the concentrations were compared with those obtained from fly caught in the south end of the "mbuga"

and at a distance of over a mile from the pools. The captured fly were marked and liberated.

TABLE XX.

Combined Statistics for both Water-holes						Statistics for the Fly Population of the "Mbuga"					
Date	Total	♂%	♀%	♀% of old fly	Young fly %	Date	Total	♂%	♀%	♀% of old fly	Young fly %
26.ii.29	367	51	49	42	27	26.ii.29	120	53	47	43	22
1.iii.29	155	59	41	32	29	4.iii.29	136	56	44	39	21
4.iii.29	142	61	39	36	26	5.iii.29	101	58	42	38	17
6.iii.29	33	Total	too sm	all to	use	6.iii.29	131	57	43	39	22
Total ... 697						Total ... 488					
Mean percentages		57	43	37	27	Mean percentages		56	44	40	21

Clearly there is striking agreement between the percentages obtained from the different places (Table XX). The total female per cent. and the female per cent. among old fly are very similar in each case. Obviously the fly concentration around the pools is not a female centre.

From this evidence it is considered that the concentration around the water-holes is an aggregation of fly recruited from the typical "mbuga" community; in no sense is it composed of elements other than those found in the surrounding "mbuga." These results were verified in the second investigation of June 1929.

Experiment 3. --To throw light upon this point, complete catches out were made at the pools, all the fly being marked; different colours were used for each day. After painting, great care was taken to prevent any of the marked fly from following the party.

TABLE XXI.

Number of Fly painted at Pools		367		162		142		33	
		No. recaptured	% recaptured	No. recaptured	% recaptured	No. recaptured	% recaptured	No. recaptured	% recaptured
When recaptured at pools	Up to 1 day later ...	—	—	15	9.0	6	4.0		
	Up to 2 days „ ...	—	—	—	—	—	—	Concen-	
	Up to 3 „ „ ...	1	0.3	—	—	—	—	tration	
	Up to 4 „ „ ...	1	0.3	—	—	—	—	disper-	
	Up to 5 „ „ ...	—	—	—	—	—	—	sed	
	Up to 6 „ „ ...	3	0.8	—	—	—	—		
	Up to 7 „ „ ...	—	—	—	—	—	—		
	Up to 8 „ „ ...	—	—	—	—	—	—		

The table (XXI) shows that, up till one day later, only a small percentage of the marked fly were still in the vicinity of the pools, but after this less than 1 per cent. were found; the concentration, however, still existed.

After one day, this aggregation of fly was composed almost entirely of new individuals; the sex proportions of the fresh population were nearly the same as those of the last, and hence of the general "mbuga" fly. From this it was concluded that the concentration had been re-stocked from the surrounding community. In the first instance, the "mbuga" population is probably recruited from the neighbouring *Berlinia* woods (*vide* p. 242). Marked fly were recaptured at long distances from the pools; this shows that the original population really did migrate, and that when the writer revisited the water-holes, the marked fly were absent, not inactive.

A possible Explanation of this Problem.—It has been suggested that the hungry individuals of the *Berlinia* woods fly into the "mbuga" in search of food (*vide* p. 44). In this case, since there is no water in the holes, there is no longer any game in the hunting ground.

As the fly search the "mbuga" for a meal, they must often cross the numerous paths that were made by herds of game when approaching the water-holes. It is possible that fly are attracted to follow these paths, all of which converge upon the pools; should this happen, many fly will meet around the water-holes. Owing to the abundant indications of recent visits of animals, the tsetse may be inclined to wait in the vicinity, in the expectation that animals will appear. Probably the fly will be exceedingly hungry by the time that they have waited for some hours in vain, and will attack with vigour any man who may come to the spot. Should nothing come, the fly will move off in search of more satisfactory feeding grounds. In the meanwhile fresh individuals have arrived, and these will wait until impatient, when they will also leave.

Thus one has a continuous stream of fly, arriving, waiting, and finally leaving. This would account for the concentration of fly around the pools composed of ever-changing individuals.

It is impossible to say what senses are employed by *G. morsitans* in following the paths, as little is known about the efficiency of the optical and olfactory organs of this species. Should tsetse hunt by sight, then they could see the well-worn game paths and the trampled grass around the dry pools. Should they hunt by scent, they could follow the stale smell of game along the gaths until they reach the water-holes, where the scent of game is so strong that it is perceptible to human nostrils for several weeks after the dispersal of the game.

Whatever the tropism is, it is possible to regard it as being of a nature that would make the paths attractive while used by game, and then gradually less attractive as time passed and no animals used them; finally the path tropism would become so weak that no allurement would be presented to hunting fly. This would account for the gradual collapse of the concentration around the pools. On this occasion the final dispersal of the fly concentration was rather abrupt. There are two possible explanations for this:—

1. The arrival of a herd of zebra on 5.iii.29; the fly may have found it more attractive and profitable to follow the game than the old paths.

2. The heavy rain of 5.iii.29 probably destroyed the attractiveness both of the paths and of the environs of the pools.

It was unfortunate that these experiments could not be carried out on a larger scale. In all, 1,185 fly were painted. The difficulty in obtaining large figures to work with is that one has only a very limited time in which to collect results, as the concentration may collapse before the completion of the experiment.

Results of the First Investigation. —1. At certain seasons a fly concentration does exist around the pools.

2. The sex proportions of the individuals forming this concentration are similar to those of the "mbuga" fly.

3. The concentration of tsetse around the dry water-holes is composed of ever-changing individuals. Should hungry fly fail to find game, or fresh traces of game, they may be temporarily attracted to those places where game was last abundant.

Second Investigation.

By mid-March 1929 the heavy rains had broken and the water-holes were full. Since water was abundant everywhere, there was no game concentration, and consequently no aggregation of fly.

Experiment 1. —Towards the end of the rains the water-holes were kept under constant observation, so that statistical evidence could be obtained as to when the fly would start in their vicinity. The following method was employed: On entering the "mbuga" all the following fly were removed and killed. Twice stops were made in the "mbuga" before the holes were reached, so as to ascertain the approximate fly density of the area. A stop was then made at each water-hole and the fly were caught. Once fly had become considerably denser near the pools, the concentration was deemed to have commenced. Notes were kept on the game seen and upon the fresh spoor. These catches were made on sunny afternoons at about 3 p.m.

TABLE XXII.

Date ...	26.iv.29	1.v.29	16.v.29	27.v.29	7.vi.29	10.vi.29
1st Stop ...	10 fly	19 fly	18 fly	6 fly	—	—
2nd Stop ...	4 fly	15 fly	14 fly	7 fly	23 fly	36 fly
1st Water-hole ...	2 fly	11 fly	6 fly	6 fly	52 fly	104 fly
2nd Water-hole ...	5 fly	8 fly	5 fly	2 fly	18 fly	31 fly
Game seen near water-holes, and fresh spoor	1 lion seen; wart-hog spoor; spoor of one hartebeest	4 hartebeest seen; wart-hog spoor	Hartebeest spoor	Much hartebeest, wart-hog and zebra spoor; also spoor of 1 roan antelope and 1 hyaena	Spoor of hartebeest, zebra, giraffe, dikdik, wart-hog, roan antelope	Much zebra spoor; lion spoor

From Table XXII it is clear that the game started to concentrate at these pools at the end of May. By 10th June fly had definitely concentrated around the first water-hole, and so these observations were discontinued.

Experiment 2. —A number of fly were marked at the pools, while the game were still drinking there, in an endeavour to discover whether this concentration of fly consisted of the same individuals which fed upon the game that came to drink, and then waited by the pools until ready for another meal; or whether it consisted of an ever-changing population, as was shown to be the case after these holes had dried up in March.

The writer was absent at this stage in the operations, and hence is indebted to the Observer, Captain V. A. C. Findlay, for obtaining these data (Table XXIII).

TABLE XXIII.

Number of fly painted at pools		72 fly	54 fly
When	1 day later	0 fly	3 fly
recaptured	3 days later	—	0 fly
at pools	6 days later	0 fly	1 fly

Unfortunately only 126 fly were marked, so that these results do not carry much weight; however, it is indicated that the concentration is composed of ever-changing individuals.

Five more of these marked fly were retaken at the pools at later dates; the last to be recaptured was taken 19 days after the last painting. Ten others were recaptured in different parts of the bush, the last being taken 25 days after marking. It would appear that fly may revisit these pools after considerable periods.

By 17th June the water-holes were dry, and the game had ceased to visit the site of the pools, although they remained in the neighbourhood.

Experiment 3.—The following experiment was designed to show to what extent fly that had been caught at a considerable distance from the dry pools would be attracted towards them.

Accordingly, fly were marked and liberated at a point $1\frac{1}{4}$ miles south of the water-holes, but in the same *Combretum* savannah wooding, near one of the many game paths that lead to the holes. In all, 618 fly were painted. Of these, 30 were recaptured at the pools, and only 20 elsewhere in the bush. Clearly these dry water-holes have a distinct attraction for hungry fly, since 60 per cent. of the recaptured individuals were found in the fly concentration that existed in the vicinity of the pools. This aggregation of tsetse had disbanded by 8.vii.29, after which date no more marked fly were recaptured by the pools.

Results of Second Investigation.—1. No aggregation of fly exists around the pools until the game have congregated.

2. The concentration of fly existing while the game are still drinking from the holes is composed of ever-changing individuals.

3. For some weeks after the pools have become dry, and the game have left, they are still attractive to fly; tsetse marked and liberated over a mile away are also attracted to the dry water-holes.

The Sense-organs used by *Glossina morsitans* in Searching for Game.

This investigation has been designed to show the relative importance of the eyes and antennae of *G. morsitans*.

The majority of writers regard the olfactory organs as being situated mainly in the antennae (Imms, 1925; Clements & Long). Tsetse may search for game by eyesight, or they may be guided by their sense of smell. For practical reasons the writer has had to ignore the "olfactory pores" of McIndoo (1914); there appears to be considerable disagreement amongst writers as to the purpose they serve.

A large-scale field experiment and an auxiliary laboratory experiment have been carried out. The fundamental purpose of the field experiment was to compare the effects upon the hunting abilities of fly deprived of their sight, with those deprived

of the use of their antennal sense-organs. The purpose of the laboratory experiment was to find the best method of coating the eyes and antennae of fly, and to gauge the direct effect of the operation upon the health of the insect.

The Laboratory Experiment.

Many possible coating materials were tested. Table XXIV gives the initial mortality among the fly of the experiments for each of the media that were tried. The initial death-rate is taken to be the percentage of fly that have died within the first two and a half days. This mortality is considered to be due to the direct effect of the operation, and to the initial shock of the change of environment. In each case the number of controls is equal to the number of fly treated.

TABLE XXIV.

Media for Antennae				Media for Eyes			
Treatment	No. of fly treated	Initial death rate of treated fly	Initial death rate of controls	Treatment	No. of fly treated	Initial death rate of treated fly	Initial death rate of controls
Amputation of terminal antennal segment	15	27%	7%	Eyes painted with Jackson's ebony varnish	15	0%	7%
Antennae coated with a mixture of paraffin wax and vaseline M.P. 43.5C.	15	20%	7%	Eyes painted with Glasurit white enamel	15	20%	0%
Antennae coated with 1% celloidin	15	0%	7%	Eyes painted with zinc white (plasticine method)	30	23%	7%
Antennae coated with Jackson's ebony varnish	30	23%	0%				

The amputation of the terminal antennal joint gave rather a high initial death-rate; for this reason, and also because of the natural objection to mutilated insects being used for experimental work, the method was discontinued.

The mixture of vaseline and paraffin wax gave quite good results; however, it is a difficult medium to work with, when one is dealing with antennae as small as those of *G. morsitans*. The writer never felt confident that the antennae had been completely coated with the mixture.

Celloidin (1 per cent.) gave good results, in that it had no ill effects upon the fly; however, it proved unsatisfactory in the field, as it was found that, after some days, the celloidin might flake off the antennal fossa and leave the organs exposed. Owing to the speed with which it dries it is a difficult medium to work with in a dry and warm climate.

Finally, black varnish was used. Despite a rather high initial death-rate, this medium was employed for the greater part of the field experiment. It gave excellent results, and not a single recaptured fly had its antennae free.

The finding of a suitable medium for painting the eyes of fly was exceedingly difficult. Black varnish and white enamel proved useless, as the tsetse would spend hours cleaning their eyes, until finally they had scraped off the covering. In the end zinc

white was used; the fly were prevented from trying to remove it until the paint had dried, after which they were unable to make any impression upon the shiny coating. This was quite a satisfactory method, though not ideal.

In the laboratory experiments described, each tsetse was separately housed in a large specimen tube, a square of muslin being tied over the mouth. The fly were given the opportunity to feed after the operation, but having fed, they would not be given another chance until 48 hours afterwards. This method proved very successful, since controls were kept alive in their tubes for as long as three months.

In order to carry out the marking and the painting of the eyes the legs of the fly are embedded in plasticine, so that the insect is incapable of movement, and can make no attempt to clean its eyes with the fore legs. The upper surface of the thorax is then painted with the differential colour, Blanco, dyed with inks, being employed for marking. A spikelet from the inflorescence of a grass is used for applying the paint. A small blob of the medium is taken up on the spikelet, and is applied to the eye. If the paint is of the right consistency it will flow over the convex surface of the organ, covering the whole. The tsetse, embedded in the plasticine, is then put on one side for about ten minutes, until the paint has dried, when the fly is examined under a lens in case the paint has contracted off part of the surface and left a few facets exposed. If the coating is satisfactory, the fly is gently dug out of the plasticine with a penknife and liberated. The fly suffers no visible injury from this embedding process and is quite capable of flying away.

In coating the antennae with black varnish, the fly is held between the forefinger and thumb, the proboscis being held down by the thumb. A very small blob of the medium is taken up on a grass spikelet and applied to the frontal lunule, at the base of the antennae; the varnish runs down the antennal fossa, coating the inner surface of the organs. The large terminal joints are pressed down into this minute pool of varnish, the medium oozing up and completely covering the outer surface. Care should be taken to see that each arista has also been stuck down. When finished, the organs are completely embedded within the antennal fossa. The fly is then released.

The proboscis was held down in the first place, because, if it is in its normal horizontal position, the varnish may run down under the vibrissae to the mouth-parts. There is no risk of this happening after the fly is liberated, as the varnish rapidly loses its viscosity. The plasticine operation is unnecessary, as the fly is unable to reach the antennal fossa with its fore-legs, and hence cannot remove the medium.

A series of laboratory experiments were carried out with the fly treated in various ways, in order to compare their longevity and feeding abilities with those of the controls.

1. *Antennae treated.*—The effect upon the fly of the various media used for the antennae is given in the accompanying table (Table XXV). It will be seen that the fly whose antennae had been tampered with fed less often than the controls, and that they were not so healthy as the normal fly. The tsetse that had had the third antennal joint removed, and those that had been treated with black varnish, yielded the highest death-rates at the end of the 30-day periods; they also displayed a decreased readiness to feed. In each case there was no doubt that the sense-organs of the antennae had been rendered functionless.

Those fly that had been treated with either a vaseline-paraffin mixture or celloidin were healthier; however, it was exceedingly difficult to determine to what extent their antennae were coated.

In the writer's original tables there is no exception to the statement that, over an equal number of days, the treated fly fed less often than the controls; however,

TABLE XXV.

Antennae

Terminal Segment amputated			Control Fly		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	15	—	Alive after 0 day ...	15	—
" " 2½ " ...	11	0.25	" " 2½ " ...	14	0.00
" " 10 " ...	6	1.40	" " 10 " ...	13	1.00
" " 20 " ...	5	5.00	" " 20 " ...	12	5.00
" " 30 " ...	1	8.00	" " 30 " ...	8	13.00
Average no. of feeds of the one fly alive after 30 days ... 8.00			Average no. of feeds of the 8 fly alive after 30 days ... 14.00		
Coated with Vaseline-Paraffin Wax			Control Fly		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	15	—	Alive after 0 day ...	15	—
" " 2½ " ...	12	0.30	" " 2½ " ...	14	0.00
" " 10 " ...	7	2.80	" " 10 " ...	12	2.00
" " 20 " ...	5	6.50	" " 20 " ...	11	8.00
" " 30 " ...	4	11.00	" " 30 " ...	9	13.00
Average no. of feeds of the 4 fly alive after 30 days ... 11.00			Average no. of feeds of the 9 fly alive after 30 days ... 14.00		
Coated with Celloidin 1%			Control Fly		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	15	—	Alive after 0 day ...	15	—
" " 2½ " ...	15	—	" " 2½ " ...	14	1.00
" " 10 " ...	13	2.50	" " 10 " ...	14	—
" " 20 " ...	11	5.00	" " 20 " ...	14	—
" " 30 " ...	9	9.00	" " 30 " ...	10	13.25
Average no. of feeds of the 9 fly alive after 30 days ... 10.00			Average no. of feeds of the 10 fly alive after 30 days ... 13.67		
Coated with Black Varnish			Control Fly		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	30	—	Alive after 0 day ...	30	—
" " 2½ " ...	23	0.00	" " 2½ " ...	30	—
" " 10 " ...	18	0.75	" " 10 " ...	29	1.00
" " 20 " ...	8	4.00	" " 20 " ...	28	10.00
" " 30 " ...	1	8.10	" " 30 " ...	26	12.00
Average no. of feeds of the one fly alive after 30 days ... 11.00			Average no. of feeds of the 26 fly alive after 30 days ... 14.30		

in these abridged tables a false impression is sometimes given during the earlier stages of the experiment, owing to the long interval between $2\frac{1}{2}$ and 10 days. Clearly, if a control died on the third day, and a treated fly on the 9th, it would appear in these tables as if the treated fly had fed more often than the control; which it would have done, but only because it had had a longer time. It was observed that the controls would feed readily, but that the treated fly needed much coaxing. This experiment indicates that the fly's readiness to feed is affected by tampering with its antennae.

TABLE XXVI.

<i>Eyes</i>					
<i>Coated with Black Varnish</i>			<i>Control Fly</i>		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	15	—	Alive after 0 day ...	15	—
" " $2\frac{1}{2}$ " ...	15	—	" " $2\frac{1}{2}$ " ...	14	—
" " 8 " ...	14	3.00	" " 8 " ...	13	2.00
Average no. of feeds of the 14 fly alive after 8 days ... 4.80			Average no. of feeds of the 13 fly alive after 8 days ... 4.80		
<i>Coated with Glasurit White Enamel</i>			<i>Control Fly</i>		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	15	—	Alive after 0 day ...	15	—
" " $2\frac{1}{2}$ " ...	12	—	" " $2\frac{1}{2}$ " ...	15	—
" " 10 " ...	11	2.00	" " 10 " ...	14	5.00
Average no. of feeds of the 11 fly alive after 10 days ... 5.00			Average no. of feeds of the 14 fly alive after 10 days ... 4.92		
<i>Coated with Zinc White (Plasticine method)</i>			<i>Control Fly</i>		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	30	—	Alive after 0 day ...	30	—
" " $2\frac{1}{2}$ " ...	23	0.43	" " $2\frac{1}{2}$ " ...	28	0.50
" " 10 " ...	21	2.50	" " 10 " ...	27	5.00
" " 20 " ...	15	7.20	" " 20 " ...	24	6.30
" " 30 " ...	15	—	" " 30 " ...	22	10.00
Average no. of feeds of the 15 fly alive after 30 days ... 13.80			Average no. of feeds of the 22 fly alive after 30 days ... 14.40		

The initial death-rate is taken to represent the direct effect of the operation upon the fly. It is suggested that after this the tsetse is indirectly affected by a decreased readiness to feed, resulting in abnormally long intervals between each meal. This probably undermines the health of the fly and results in reduced longevity.

2. *Eyes treated.*—The effect upon the fly of the various media used for the eyes is given in Table XXVI. It will be seen that those fly which had been blinded fed

approximately as often as the controls; also, that after the first two-and-a-half days, they were much healthier than those fly that had had their antennae coated. A comparison between the 30 fly with the antennae varnished black, and the 30 fly with the eyes coated with zinc white, gives the following results:—In each case the initial death rate was 23 per cent.; hence the direct shock of the operation upon the fly was similar. The fly with coated antennae showed a decreased readiness to feed when placed upon a calf, and by the 30th day only 3 per cent. were alive. The blinded fly showed no unwillingness to feed when placed upon the animal, and by the 30th day 50 per cent. were still alive. Hence, given an available food supply, fly that have been blinded are not incapacitated from feeding, and have greater longevity than fly with functionless antennae.

3. *Eyes and Antennae treated.*—The effect of coating both eyes and antennae of a fly is shown in Table XXVII. Clearly this treatment has very serious results upon the health of the fly. The initial death-rate was 77 per cent., and none of the survivors managed to live more than twenty days. The fly showed an unwillingness to feed, presumably because their antennae had been coated.

TABLE XXVII.
Eyes and Antennae

<i>Eyes coated with Zinc White, Antennae coated with Black Varnish (Plasticine method)</i>			<i>Control Fly</i>		
Time period	No. of fly alive	Av. no. of feeds of dead fly	Time period	No. of fly alive	Av. no. of feeds of dead fly
Alive after 0 day ...	30	—	Alive after 0 day ...	30	—
" " 2½ " ...	7	0·00	" " 2½ " ...	30	—
" " 10 " ...	4	2·33	" " 10 " ...	29	3·00
" " 20 " ...	0	4·50	" " 20 " ...	26	7·00
" " 30 " ...	—	—	" " 30 " ...	20	12·50
Average no. of feeds of the fly alive after 30 days ...			Average no. of feeds of the 20 fly alive after 30 days ...		
... .. —			... .. 14·40		

In a further comparison of the feeding ability of blind fly and of those having the olfactory organs functionless, seventy fly had their eyes painted with zinc white, and the average number of feeds of the survivors after 30 days was fourteen. Whereas with seventy fly that had their antennae coated with black varnish, the average number of feeds of the survivors after 30 days was 7·5.

The Field Experiment.

The purpose of this was to ascertain whether *G. morsitans* uses sight or the olfactory organs situated in the antennae when searching for game.

During a month 3,000 fly were treated, differentially marked, and liberated:—750 had their eyes painted; 750 had their antennae painted; 750 had their eyes and antennae painted; 750 were marked and liberated as controls. The technique employed was similar to that already described. In the initial stages of the experiment black varnish was used for the eyes, and celloidin for the antennae. In a few cases it was found that the medium had been removed by the fly, and so afterwards zinc white was used for the eyes and black varnish for the antennae; these proved satisfactory.

The fly were treated and liberated at a fixed spot in the *Combretum* "mbuga," between Trees 5 and 6 of the S.E. round. All fly recaptured had to be at least a mile from the site of liberation. No re-catching was attempted within a shorter radius.

It was assumed throughout the experiment that, should a treated fly be capable of travelling at least a mile from the site of liberation and then be attracted by the human bait presented by the catches, it might be considered as a fly still in retention of its normal hunting faculties. Every fly recaptured was carefully examined under a lens, in order to make certain that its sense organs were still completely coated; having noted the particulars, the fly was killed.

Table XXVIII gives details of the fly recaptured out of the 3,000 treated.

TABLE XXVIII.

Details of Re-captured Fly				Controls
Operations	Eyes coated	Antennae coated	Eyes and antennae coated	
Number re-captured with organs free ...	15	6	9	—
Number re-captured with organs well coated...	0	66	0	70

It will be seen from the second horizontal column of figures, that no single fly was recaptured with its eyes still covered, whereas 66 fly with their antennae completely coated and 70 controls were retaken. It may seem strange that despite the 23 per cent. initial death-rate occurring among fly with coated antennae under laboratory conditions, the number recaptured in the field should be almost the same as that of the controls. A possible explanation is that, owing to the long periods between meals, these treated fly are more active and hence come to the catchers in greater numbers than the controls, which feed often and so have many inactive periods during the initial stages of digestion.

Unfortunately a few fly succeeded in cleaning their eyes; four-fifths of these date from the early days of the experiment when black varnish was used; since zinc whitewas adopted as the coating material, there has been hardly any trouble from fly cleaning their eyes.

The six fly that were recaptured with clean antennae had all been treated with celloidin; however, since black varnish was used, not a single fly managed to free its organs. Of the nine fly recaptured that had had both eyes and antennae painted, all had managed to free their eyes from the black varnish, but none had freed their antennae.

Thus it appears that, unless a blinded fly should be able to regain its sight, it will never be seen again; its antennae cannot compensate for loss of vision. A fly whose eyesight is normal, but whose antennae are well coated, is quite capable of successfully finding game. These results indicate that *G. morsitans* hunts mainly by sight, and that the olfactory organs of the antennae are not sufficiently developed to be of use in searching for food.

It was observed, when treating and liberating fly in the bush, that fly having their eyes painted seemed to lose their sense of direction. Some would buzz round and round, ascending the while, and finally disappear. Others would fly off at a low level in a zig-zag course, and often would strike a tree, or collide with grass stems. Others would sit on the ground within a couple of feet of the writer and try

to clean themselves; despairing in this, they would rise into the air, and often blunder straight into him, whereupon they would settle, and having found a suitable spot, would start probing.

Fly with their antennae painted behaved in a normal manner. On being liberated they would fly off and presumably start cleaning themselves. Some time later a few might return and settle on the boys; however, they rarely probed. Having been attracted by the moving object, and having settled upon it, they then seemed to be at a loss to know what next to do.

The writer would prefer to have obtained a larger number of recaptures upon which to base his conclusions. When dealing with an insect as common as *G. morsitans*, and which travels considerable distances, only a colossal experiment, with a large staff of trained catchers, would make this possible. Of the controls 9 per cent. were retaken. Thus, in order to retake a thousand controls with the same sized native staff, one would have to mark 10,714 fly. This number of fly would have to be treated for each of the three remaining operations, giving a total of 42,856 fly. To coat the eyes, $2\frac{1}{4}$ minutes is needed per fly. From this it will be realised how impracticable a large scale experiment would be.

As compared with experiments of other workers who have studied the sense-organs of bees, moths, and other insects, the numbers employed in this investigation have been decidedly large. In most of the experiments described in the literature upon the subject the numbers employed have been less than 100.

General Conclusions.

From the results of the laboratory and field experiments it is indicated that:—

G. morsitans hunts its food entirely by eyesight; the olfactory organs of the antennae are only operative over a very limited field. Possibly they stimulate the fly to probe, and are capable of selecting the best places for the insertion of the proboscis.

Without its antennae *G. morsitans* appears to have difficulty in correlating its desire to follow and alight upon a moving object with its desire for food.

It is suggested that the normal action of obtaining food consists of a visual and an olfactory tropism. The stimulus of seeing a moving object induces the reflex of following that object; the stimulus of smelling the object induces the reflex of probing. Should the fly be unable to see the object, it cannot follow it. Should the fly be unable to smell the object, it will be unwilling to probe. Should the fly be exceedingly hungry, a new stimulus is brought into play, which induces probing. This stimulus is sufficiently powerful to be able to induce probing when the olfactory organs are rendered functionless: e.g., if an exceedingly hungry fly is placed in a corked tube, it will often try to probe through the glass in an effort to feed on the finger placed on the outside. On this supposition the writer explains the ability to feed of the fly deprived of its antennae. Only when the stimulus created by hunger has reached a critical point will the fly be induced to probe.

In the laboratory experiments the intervals between meals was exceptionally long, because the fly, deprived of its olfactory organs, had to wait until the hunger stimulus was sufficiently great to induce the reflex of probing.

V. GENERAL SUMMARY.

Fly (*Glossina morsitans*) emerge from their puparia during both short and long dry seasons. During both rainy seasons emergence is extremely low.

Fly density is greatest at the end of the heavy rains. The cold spell and the fires cause a great drop in density. *G. morsitans* is scarcest at the end of the long dry season and during the light rains. At the end of both rains a great emergence

takes place, resulting in a large increase in density. The climatic rigours of the short dry season cause a drop in fly numbers. Density remains steady at a medium high level throughout the heavy rains.

The order of fly preference for the vegetational communities is as follows:—

1st	...	...	...	<i>Brachystegia microphylla</i> .
2nd	...	...	...	<i>Acacia usambarensis</i> .
3rd	...	...	...	<i>Berlinia globiflora</i> .
4th	...	...	...	<i>Combretum savannah</i> .
5th	...	...	...	<i>Acacia spirocarpa</i> .
6th	...	...	...	Gall acacias.
7th	...	...	...	Open "mbuga."
8th	...	...	...	Extensive cultivation.

Females only appear in their true numbers in open "mbuga" country. These open areas are considered to be the feeding grounds, to which fly of both sexes resort for a meal. Having fed, they are believed to return to the shade of the woods.

When the savannah shrubs are green and umbrageous, tsetse are scattered throughout the bush. When the country is leafless, and later swept by fire, the surviving fly concentrate in their true habitats—the *Berlinia-Brachystegia* communities and light thickets.

Only large game movements cause noticeable effects upon the fly community. They invariably cause a marked increase in the female per cent.

Puparia collected from the Kikori bush give the natural female percent. as 53, and the percentage of parasitism by *Thyridanthrax abruptus* as 9.7.

When game congregate around certain pools a fly concentration is formed. After the holes have dried and the game have left, a fly concentration remains, which is composed of ever-changing individuals, recruited from the hungry, hunting fly of the "mbuga."

Fly appear to hunt entirely by sight. The olfactory organs of the antennae are operative only over a very limited field. The stimulus of smelling the prey is believed to produce the reflex of probing. If the antennae are rendered functionless, the fly is less ready to feed.

A Concept of the Fly Community based upon the Evidence already given.

The true habitats of the fly coincide with the major breeding sites; they are characterised by perennial, if variable, shade and poor visibility. In the Eastern Kondoa Fly Belt, the *Berlinia-Brachystegia* wooding and small thickets form such habitats.

Fly multiply during the favourable season that follows the rains. When the sky is cloudy, and even the savannah shrubs are green and umbrageous, tsetse are scattered throughout the bush.

Fly are scarce during the unfavourable dry season. They concentrate within their true habitats, when the open country is leafless. The *Berlinia-Brachystegia* woods are considered to be the centres from which the fly advance or to which they retreat, according to the season.

The open "mbugas" are the feeding grounds for both sexes of fly. At no season do they form a habitat. Hungry fly leave the shade of the woods and rove through the open "mbuga" searching for game; the good visibility of such country is well suited to insects which appear to hunt by sight.

It is believed that tsetse do not fly through the bush until attracted by a moving object, but that they definitely hunt, following paths and visiting recent haunts of game. Having fed, the fly make for the nearest stand of shady woods and there

digest. There is no indication that fly return to the same habitat after each meal. Should there be no open country, then a road may form a feeding ground. These areas can be recognised by the relatively high female percentage and the starved condition of the fly. The tsetse taken in the true habitats have a very low female percentage and are well fed. These woods, however, are not considered to be male areas. Females are believed to be as abundant as males within the true habitat; however, they are inactive between meals, and usually only fly when hungry and in need of food.

Males are considered to be attracted by movement alone, whereas females need this tropism, as well as that of hunger. This reluctance on the part of the females is considered to be engendered by their fear of assaults from males. It is a common sight to see a female attacked by several males, which will grapple and force her to the ground, where the fight for possession may last for some seconds. In very dense fly, such as is usually found in the true habitats, a female may be attacked by as many as five individuals of the opposite sex. In belts of thin fly the female inactivity is not nearly so marked.

G. morsitans is sometimes found in exceptionally large numbers in certain woods. A particularly suitable environment may attract many individuals until an aggregation is formed; however, no evidence can be found to show that such a community is of a social nature.

Conclusion and Acknowledgments.

The writer trusts that this account will give some idea of the intimate relationships that exist between *G. morsitans* and its environment; also, that it will become apparent that the study of the ecology of the fly is of vital importance for the attainment of a better understanding of the laws that govern its existence.

In conclusion, the writer wishes to express his thanks to Dr. J. F. V. Phillips for the invaluable advice and criticism constantly given throughout the investigation; also to Capt. V. A. C. Findlay, the Observer, for often having carried on the work of the station in the writer's absence. He is indebted to Mr. N. H. Vicars-Harris for assistance in typing and assembling the manuscript.

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1. --- Motor Road.
2. Foot Path.
3. -o-o- Route of Fly Rounds.
4. (concentric circles) Form Lines.
5. [small squares] Native Habitations.
6. [wavy line] Stream.
7. [wavy line] *Typha australis* or rank grass in stream bed.
8. [cloud shape] "Mbuga" or open steppe
10. [stippled box] Gall *Acacia* (*Ac. formicarum* or *drepanolobium*).
11. [red box] *Acacia spirocarpa*.
12. [red box with horizontal lines] *Acacia usambarensis*.
13. [yellow box] *Acacia verugera*.
14. [dark blue box] *Acacia xanthophloea*.
15. [orange box] *Acacia campylocantha*.
16. [blue box with diagonal lines] *Combretum-Terminalia* Savannah.
18. [light green box] *Brachystegia microphylla* or *Berlinia* communities.
19. [orange box with diagonal lines] *Acacia spirocarpa* with underwooding of :- *Dalbergia* sp. *Terminalia* sp.
20. *Commiphora* sp. *Lannea humilis*.
21. *Combretum* sp.
22. [green box with vertical lines] *Acacia usambarensis* with underwooding of *Combretum-Terminalia*.
23. [dark blue box] Transition belt between *Brachystegia microphylla*-*Berlinia* Community, and *Combretum-Terminalia* Savannah.
24. [orange box with vertical lines] Very impure *Combretum* Savannah intermixed with *Commiphora* sp.
25. *Vitex* sp.
26. *Parinarium* sp.
28. [hatched oval] Thicket.

VEGETATIONAL MAP OF THE KIKORI DISTRICT.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Bureau of Entomology, between 1st January and 31st March, 1930, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance :—

Mr. T. J. ANDERSON, Government Entomologist :—4 Coleoptera ; from Kenya Colony.

Mr. T. M. AUSTIN :—1 species of Aleurodidae ; from Jamaica.

Mr. A. DE AZEVEDO :—26 Curculionidae and 5 early stages ; from Brazil.

Mr. E. BALLARD :—21 Rhynchota ; from Egypt.

Prof. H. A. BALLOU :—7 Lepidoptera ; from Trinidad.

Mr. G. E. BODKIN, Government Entomologist :—15 Lepidoptera and 3 Ticks ; from Palestine.

Dr. G. BONDAR :—89 Coleoptera and 2 larvae, 22 Hymenoptera, and 9 Rhynchota ; from Brazil.

Mr. H. E. BOX :—26 Diptera, 800 Coleoptera, 209 Parasitic Hymenoptera, 158 other Hymenoptera, 2 Lepidoptera, and 3 Rhynchota ; from Tropical America.

Prof. W. H. BRITTAIN :—43 Coleoptera and 102 Lepidoptera ; from Canada.

Dr. P. A. BUXTON, London School of Tropical Medicine :—4 Culicidae, 18 Tabanidae, 15 other Diptera and 2 pupa-cases ; from various localities.

CHIEF ENTOMOLOGIST, PRETORIA :—79 Coleoptera, 12 Parasitic Hymenoptera, 1 species of Aleurodidae, 29 other Rhynchota, and 12 Orthoptera ; from South Africa.

Dr. R. N. CHRYSTAL :—64 Parasitic Hymenoptera ; from Oxford.

Mr. L. D. CLEARE, Junr., Government Entomologist :—21 Diptera, 4 Coleoptera, 27 Parasitic Hymenoptera, 25 other Hymenoptera, 14 Lepidoptera, 2 species of Coccidae, 1 species of Aphidae, 5 other Rhynchota, 10 Mites, 2 *Peripatus*, 16 Slugs, and 6 Shrimps ; from British Guiana.

Prof. T. D. A. COCKERELL :—2 Coleoptera, 6 Parasitic Hymenoptera, 61 other Hymenoptera, 4 Lepidoptera, 3 Rhynchota, 2 Orthoptera, 2 Planipennia, and 3 Odonata ; from various localities.

Mr. G. H. CORBETT, Government Entomologist :—4 Diptera, 25 Coleoptera, and 2 early stages, 1,285 Parasitic Hymenoptera, 20 Formicidae, 35 Lepidoptera, 47 Thysanoptera, 11 species of Coccidae, 22 species of Aphidae, 69 other Rhynchota, and 3 tubes of Parasitic Worms ; from the Federated Malay States.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—370 Coleoptera ; from Kenya Colony.

Mr. H. S. CUNNINGHAM, Plant Pathologist :—2 Lepidoptera and 1 species of Coccidae ; from Bermuda.

Mr. A. CUTHBERTSON, Assistant Entomologist :—49 Diptera, 11 Parasitic Hymenoptera, 7 other Hymenoptera, and 4 Rhynchota ; from Southern Rhodesia.

Dr. J. DAVIDSON :—115 Diptera, 81 Hymenoptera, 76 Thysanoptera, and 2 species of Aphidae ; from South Australia.

Mr. P. R. DUPONT :—2 Parasitic Hymenoptera, 12 Lepidoptera and 30 larvae, and 11 species of Coccidae ; from the Seychelles.

Prof. J. C. FAURE :—80 Coleoptera, 31 Parasitic Hymenoptera, 124 other Hymenoptera, 4 Rhynchota, and 125 Orthoptera ; from South Africa.

Mr. T. B. FLETCHER, Imperial Entomologist :—2 Orthoptera ; from India.

Mr. J. C. M. GARDNER, Systematic Entomologist :—112 Coleoptera and 35 Chalcididae ; from the United Provinces, India.

Dr. CL. GAUTIER :—12 Parasitic Hymenoptera ; from France.

Mr. F. D. GOLDING, Government Entomologist :—2 Bombyliidae, 16 Coleoptera, 8 Hymenoptera, 18 Lepidoptera, 21 Rhynchota, 3 Orthoptera, and 3 Ephemeridae ; from Southern Nigeria.

Mr. W. GREENWOOD:—14 Diptera, 21 Coleoptera, 8 Parasitic Hymenoptera, 97 Lepidoptera, 13 Isoptera, 6 Thysanoptera, 23 Rhynchota, 2 Hemerobiidae, 2 Odonata, and 50 Mites; from the Fiji Islands.

Mr. W. B. GURNEY, Government Entomologist:—22 Parasitic Hymenoptera; from New South Wales, Australia.

Mr. G. L. R. HANCOCK, Assistant Entomologist:—123 Tabanidae, 4 *Glossina*, 158 other Diptera and 10 early stages, 201 Coleoptera, 27 Parasitic Hymenoptera, 67 other Hymenoptera, 269 Lepidoptera, 20 Rhynchota, 9 Orthoptera, 3 Planipennia, 12 Ephemeridae, 6 Perlidae, 3 Trichopterous larvae, 7 Collembola, 100 Crustacea, and 4 tubes of Algae; from Uganda.

Mr. E. HARGREAVES, Government Entomologist:—10 Culicidae, 31 other Diptera, 19 Coleoptera, 6 Hymenoptera, 18 Lepidoptera, 3 species of Coccidae, 8 other Rhynchota, and 2,000 Orthoptera; from Sierra Leone.

Dr. F. G. HOLDAWAY:—10 Diptera, 18 Coleoptera, 32 Parasitic Hymenoptera, 7 other Hymenoptera, and 2 tubes of Earthworms; from France.

Mr. G. H. E. HOPKINS, Medical Entomologist:—2,415 Culicidae, 3,870 Coleoptera, 1,400 Rhynchota, and 32 Fishes; from Uganda.

Mr. M. A. HUSAIN, Government Entomologist:—100 Thysanoptera; from the Punjab, India.

Mr. F. P. JEPSON, Assistant Entomologist:—8 Diptera and 2 pupa cases, 5 Curculionidae, and 400 Isoptera; from Ceylon.

Dr. H. W. KUMM:—4 Culicidae; from Southern Nigeria.

Dr. W. A. LAMBORN, Medical Entomologist:—54 Culicidae, 16 Tabanidae, 16 other Diptera, 18 Coleoptera, 3 Parasitic Hymenoptera, 2 other Hymenoptera, and 5 Lepidoptera; from Nyasaland.

Dr. S. LEEFMANS:—8 Curculionidae and 10 Lepidoptera; from Java.

Sir G. A. K. MARSHALL, C.M.G., F.R.S.:—95 *Glossina*, 3 *Stomoxys*, 7 other Diptera, 655 Coleoptera, 7 Parasitic Hymenoptera, 8 other Hymenoptera, 35 Lepidoptera, 110 Rhynchota, 8 Orthoptera, 9 Planipennia, 2 Odonata, 32 Ephemeridae, and 16 Trichoptera; from Africa.

Mr. G. A. MAVROMOUSTAKIS:—28 Orthoptera; from Cyprus.

Mr. A. P. D. MCCLEAN:—1 species of Coccidae; from Natal.

Mr. C. MENOZZI:—2 Parasitic Hymenoptera; from Italy.

Dr. D. MILLER, Chief Entomologist, Cawthron Institute:—2 species of Aphidae; from New Zealand.

Mr. H. M. MORRIS, Government Entomologist:—17 Rhynchota; from Cyprus.

Mr. K. R. S. MORRIS:—2 Orthoptera; from the Gold Coast.

MUSÉE DU CONGO BELGE, Tervueren:—4 Lepidoptera; from the Belgian Congo.

Dr. S. A. NEAVE:—5 Diptera, 4 Coleoptera, 1 species of Coccidae, 1 species of Aphidae, and 8 other Rhynchota; from the Canary Islands.

Mr. R. W. PAINE:—2 Coleoptera and 46 Parasitic Hymenoptera; from Java.

Prof. G. PAGONI:—7 Coleoptera, 21 Parasitic Hymenoptera and number of cocoons; from Italian Somaliland.

Mr. R. H. LE PELLEY:—6 Coleoptera, 96 Parasitic Hymenoptera, 140 Formicidae, 5 Thysanoptera, 11 species of Coccidae, 2 species of Aphidae, 12 other Rhynchota, and 10 Psocidae; from Kenya Colony.

Mr. A. W. J. POMEROY, Government Entomologist:—9 parasitised *Glossina* puparia; from the Gold Coast.

Mr. A. H. RITCHIE, Government Entomologist:—40 Parasitic Hymenoptera, 34 Lepidoptera, and 3 pupa cases; from Tanganyika Territory.

Mr. H. W. SIMMONDS, Government Entomologist:—6 Cecidomyiidae, 145 Parasitic Hymenoptera, 21 Lepidoptera, and 10 Thysanoptera; from the Fiji Islands and Trinidad.

Mr. E. R. SPEYER :—4 Formicidae, 1 species of Aleurodidae, 60 Thysanura, and 10 Mites ; from Tunisia.

Mr. C. B. SYMES, Medical Entomologist :—11 *Tabanus*, 143 *Glossina*, and 2 other Diptera ; from Kenya Colony.

Mr. T. H. C. TAYLOR, Assistant Entomologist :—68 Parasitic Hymenoptera and 8 Lepidoptera ; from the Fiji Islands.

Mr. H. THOMANN :—15 Parasitic Hymenoptera ; from Switzerland.

Mr. R. W. E. TUCKER, Government Entomologist :—7 Diptera and 3 pupa-cases, and 30 Lepidoptera ; from Barbados.

Mr. F. W. URICH :—44 Culicidae, 7 Rhynchota, and 2 Orthoptera ; from Trinidad.

Mr. A. M. VANCE :—30 Parasitic Hymenoptera ; from France and Italy.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—58 Tabanidae, 348 other Diptera, 500 Coleoptera, 80 Parasitic Hymenoptera, 78 other Hymenoptera, 228 Lepidoptera, 41 Rhynchota, 2 Orthoptera, 2 Embiidae, 274 Planipennia, 24 Ephemeridae, and 11 Trichoptera ; from the Sudan.

Dr. F. ZACHER :—17 Coleoptera, 20 Parasitic Hymenoptera, and 2 Lepidoptera from Europe and Africa.

ENTOMOLOGICAL ASPECTS OF LAC RESEARCH IN INDIA.

By P. M. GLOVER,

Entomologist, Indian Lac Research Institute.

(PLATE IX.)

Lac is the resinous encrustation secreted by the scale-insect, *Laccifer* (*Tachardia*) *lacca*, Kerr (COCCIDAE). Research with a view to the improvement in quality and quantity of this secretion consists therefore in a study of the Coccid itself and the hosts on which it lives, and the relationship between the insect and its hosts. It also entails an investigation of the insect friends and enemies of the Coccid and of its hosts.

The following are the more important host-trees used for lac cultivation in India :

<i>Name.</i>		<i>Local Name.</i>		<i>Family.</i>
<i>Schleichera trijuga</i>	... ..	Kusum	... ..	Sapindaceae.
<i>Butea frondosa</i>	... ..	Palas	... ..	Leguminosae.
<i>Zizyphus jujuba</i>	... ..	Ber	... ..	Rhamnaceae.
<i>Zizyphus xylopyra</i>	... ..	Ghont	... ..	Rhamnaceae.
<i>Acacia catechu</i>	... ..	Khair	... ..	Leguminosae.

A large number of lesser known hosts from diverse families, including trees, shrubs and creepers, are also utilised to a greater or less extent in different districts for the commercial production of lac, and the investigation and spreading of information with regard to these is one of the lines of research being pursued.

With regard to distribution, 90 per cent. of the lac produced in India comes from the area comprising Chota Nagpur, the Feudatory States of Orissa and the Central Provinces. Bihar and Orissa is, however, responsible for more than half the annual out-turn of lac from India. Other lac-growing areas are Assam, Burma and Sindh, also certain areas in Bengal, and the United Provinces, Hyderabad, and Bombay and Madras Presidencies.

Entomological research falls readily under three main headings: firstly, the bionomics of *L. lacca*; secondly, the parasite, hyperparasite and predator friends and enemies of the Coccid; and, thirdly, the friends and enemies of the host-trees on which the scale feeds.

Bionomics of *Laccifer lacca*.*Life-cycle.*

L. lacca has two generations in the year, except in Mysore, where it passes through three cycles in thirteen months on the host-tree, *Shorea talura*.

L. lacca grown on any host-tree except *Schleichera trijuga* completes one life-cycle, the *katki*, during the period July to October-November, male emergence occurring in September. The second cycle or *baisakhi* is longer, being from October-November to July, males emerging in March. When the Coccid is grown on *Schleichera trijuga*, the two cycles are of approximately equal duration; the first or *aghani* being from July to January-February, the males emerging in September; the second or *jethwi* from January-February to July, male emergence being in April-May.

An interesting point that is being investigated in this connection is that if *L. lacca* is grown for one crop or generation on *Schleichera trijuga* and for successive crops on any other host, it retains the *Schleichera trijuga* equal generations. The reverse, however, does not occur.

The above life-cycles vary somewhat according to the District, but represent the usual generations for the majority of Districts.

Relationship of Parasite and Host.

Research with regard to actual growth and relationship between the scale and its hosts is being conducted on the following main lines :—

Experimental inoculations are being carried out on various hosts and sequences of hosts, using known weights of brood lac for inoculation purposes. From these trees periodic samples are taken and a calculation made of the insect mortality, the ratio of males to females, and the percentage parasitisation ; finally, the weight of the yield of lac is taken. These results compiled over a number of years enable an opinion to be formed on the following points :—

1. What trees are the most suitable hosts for *L. lacca*.
2. For which generation lac should be grown on which host ; for instance, it has been found that *Acacia catechu* is only suitable as a host for the July–October, November and July–January, February crops.
3. On which host-tree *L. lacca* is least subject to parasitisation.
4. What alteration of hosts is most satisfactory.
5. The yield that may be expected from a given weight of brood.
6. The fertility of *L. lacca* grown on different hosts.

A great deal of valuable practical information has been and is being obtained and circulated as a result of these experimental inoculations.

Another line of investigation in this connection is the time and type of pruning that will leave the host in the most suitable condition for use by the Coccid ; and also the effect on the insect, and consequently on the lac produced, of cultivating and manuring the host on which the insect is grown by different methods and with various manures.

Anatomy and Morphology of L. lacca.

The anatomy and morphology of *L. lacca* is receiving attention, and results of practical importance have been obtained. It has been proved that the female insect is alive at the time of larval emergence or swarming, and that she can to some extent control the swarm, postponing it if climatic conditions are adverse. This means that lac cut from one tree to be used as " brood " to inoculate a fresh tree must not be cut too early, as cutting takes the female from her food supply, and if done prematurely the vitality of the young larvae must necessarily suffer. Similarly " brood " should not be cut too late, or many of the larvae may emerge and be lost before it can be tied to the new host. Results suggest cutting no sooner than 8–10 days before the swarm is due to emerge.

A method has been worked out by means of which the date of swarming can be forecasted with fair accuracy, depending on the examination of the developing ovules ; this method, however, requires some skill and the possession of a microscope, and is therefore unsuitable for the average cultivator. A new method is, however, being perfected by which forecasting can be carried out from the external appearance of the female cell ; this method depends on the activity of the perivaginal glands and the contraction of the female muscles causing the body to retract from the inner surface of the cell, producing a definite corresponding translucence, which can easily be observed externally. This method will enable the average cultivator to form accurate forecasts of the time of swarming.

The process of swarming has itself been investigated, and results show that while humidity plays no part in egg-laying and consequently swarming, temperature is the factor of primary importance.

The lowering of the day temperature 4° – 6° C. is sufficient to stop egg-laying temporarily and prevent swarming of larvae from the female birth-chamber. Hatched larvae confined in the birth-chamber for 3–4 days die of starvation. The lowering of the temperature 10° – 12° C. practically prevents egg-laying entirely without impairing the female vitality or affecting the progeny as regards number or sex ratio; on the temperature being raised again to normal, swarming occurs. This means that "brood lac" can be despatched for long distances at reduced temperature to prevent swarming in transit, and suffer no depreciation.

It has also been discovered that swarming that has been delayed by adverse conditions can be induced either by keeping the brood at a temperature of 24° – 28° C., or by cooling it 6° – 14° C. for 3–4 days and then bringing it to atmospheric temperature.

By means of a binocular microscope it has been found possible to distinguish between males and females among the swarming larvae; the ratio of males to females is of great practical importance, as the males secrete practically no lac and are only required to be present in sufficient numbers to ensure satisfactory fertilisation. The optimum ratio of males to females and the factors governing it are receiving attention. The female insect is capable of asexual reproduction for two successive generations, but the third generation of parthenogenetically produced larvae fail to survive; the development of these unfertilised females is in no way inferior to that of normally fertilised females. This means that the intermittent occurrence of adverse climatic conditions at the times of male emergence will not damage the lac crop.

Attempts are being made also to evolve a strain of insect that would produce resin of a superior quality. In this connection a mixed race of yellow and red cells grown on *Zizyphus jujuba* in Jodhpur is being investigated, with a view to obtaining a pure yellow strain. This is of particular interest, as the yellow cells give rise to both yellow and red larvae and of these some of the yellow turn red and some of the red turn yellow during the course of their development.

The Insect Friends and Enemies of *L. lacca*.

The damage done by insects to lac in India is enormous; a minimum estimate is 60 per cent. of the hypothetical undamaged crop, valued at about 13 crores, 60 Lakhs of rupees, or roughly ten million pounds a year. The enemies fall into two main groups, predators and parasites.

Predators.

Eublemma amabilis, Moore (Noctuidae).

The larva of this predator is one of the most serious of the lac enemies, and is to be found in practically every lac-growing area in India. The larva mines the encrustation and feeds on the living *L. lacca*, finally pupating in its chamber within the lac encrustation. There are six generations in the year, and hibernation occurs in the stored *katki* crop and in the *aghani* crop. The life-history has been worked out, and control methods are being devised. The efficacy of spraying the lac with an internal poison such as lead arsenate at the time of egg hatching is being tested, but cannot be recommended in spite of its value as a control for *Eublemma*, as it causes a high mortality in the lac insects.

The predator has a number of natural enemies whose life-histories are being investigated with a view to exploitation as controls.

a. Ephestia sp. (Pyralidae). The larva of this moth acts as a scavenger as regards lac, but also feeds on the larvae of *Eublemma*. It occurs, however, in stored crops and not in the field.

b. *Camponotus compressus*, F., and *Solenopsis geminata rufa*, Jer. (Formicidae). Both these ants attack *Eublemma* larvae.

c. *Brachymeria tachardiae*, Cam. (Chalcididae). Found as an ectoparasite of the larva and an endoparasite of the pupa of *Eublemma*.

d. *Bracon tachardiae*, Cam. (Braconidae). Ecto-parasitic on the larva and endoparasitic on the pupa of *Eublemma*.

e. *Elasmus claripennis*, Cam. (Elasmidae). Parasitic on the *Eublemma* larva; it appears to have some alternative host, which is yet to be discovered.

Holcocera pulverea, Meyr. (Tineidae).

The larva of this moth affects lac in the same way as that of *Eublemma*; though not so serious an enemy as the latter, the damage it does is extensive. It passes through six generations in the year and, like *Eublemma*, hibernates in the stored *katki* and *aghani* crops; the six generations correspond fairly closely with those of *Eublemma*. The life-history has been worked out and controls are being tested; results of spray experiments are similar to those found for *E. amabilis*.

The predator has a number of natural enemies, the life-cycles of which are being worked out and possible uses devised.

a. *Camponotus compressus*, F., and *Solenopsis geminata rufa*, Jer. (Formicidae). These two ants attack the larvae of *Holcocera* as they do those of *Eublemma*.

b. *Brachymeria tachardiae*, Cam. (Chalcididae). Found as an ectoparasite of the larva and endoparasite of the pupa of *Holcocera*. There are four and possibly five generations in the year.

c. A Chalcid (unidentified). A black species with two main emergences in the year.

d. *Apanteles tachardiae*, Cam. (Braconidae). Parasitic on the larva of *Holcocera*, and also on that of *Ephestia* sp.

e. An Ichneumonid. Parasitic on the larva.

f. A Bethyloid. Parasitic on the larva.

Parasites.

This group of enemies is responsible for a great deal of damage, and investigations are in continuation; life-histories are in some cases nearly completed. A search is being made for alternative hosts and hyperparasites with a view to exploitation as controls. Spraying as a control against predators seems to be of some value as a deterrent, but cannot be recommended, as previously mentioned. The destruction of alternative hosts is being carried out, where these are known. The following is a brief résumé:—

Apanteles fakhrukhajiae, Mahdh. (Braconidae).

A Braconid (unidentified).

An Ichneumonid. These three have been collected from lac; their function is uncertain, but it seems probable that they are parasites of lac predators and therefore friends.

Tetrastichus purpureus, Cam. (Eulophidae). A definite endoparasite of *L. lacca*, and the most numerous of the Chalcids found in connection with lac. It is hyperparasitic on *Coccophagus tschirchii*, Mahdh., and *Tachardiaephagus tachardiae*, How., both of which are lac parasites, but is of no value in this respect, as its main function is that of a lac parasite.

A spotted Chalcid (Encyrtidae). Mainly parasitic on male lac insects and occurring in each crop at about the time of male emergence, its alternative hosts are *Aspidiotus* and *Chionaspis* (Coccidae), against both of which measures are being taken as pests of the host-tree. Other alternative hosts are at present unknown.

Brasema annulicaudis, Cam. (Eupelmidae). A serious enemy of lac, parasitic on *L. lacca* and hyperparasitic on the lac friends, *Bracon tachardiae*, Cam., and *Apanteles tachardiae*, Cam. Alternative host, *Machaerota planitiae*, Dist. (Cercopidae); measures are being taken against *Machaerota* as a pest of the host-tree.

A Chalcid (Encyrtidae). A black Chalcid parasitic on lac. No alternative hosts are known.

Coccophagus tschirchii, Mahdh. (Eulophidae). A very abundant parasite of lac, which has five generations and emerges with only slight discontinuity throughout the year.

Tachardiaephagus tachardiae, How. (Encyrtidae). Also very abundant; five generations are passed in lac during the year.

Yellow Chalcids (Encyrtidae). These two Chalcids have been collected from lac in small numbers, and their function is not definitely ascertained. They are suspected, however, of being lac parasites.

General Control Methods applicable alike to Parasites and Predators.

The following general methods of control have been devised:—

1. The use of pest-free brood lac for inoculation purposes.
2. The removal of brood after two or, at most, three weeks' use.
3. The treatment of the whole fresh-cut mature crop, exclusive of the portion to be used as brood, and of all brood after use by one of the following methods: Steam-heating, fumigation, or immersion under water for 8–12 days. The adoption of this measure would reduce the numbers of insect enemies of lac in the field by more than half.

Other Insects associated with Lac.

Formicidae.—The majority of ants associated with lac are harmless, and some are even beneficial; they visit the lac for the "honey-dew" secretion passed through the anal cleft of the lac cell. Some attack the larvae of lac predators, and some pick up crawling lac larvae and males. Where this latter habit is prevalent cheap molasses can be painted round the host stem, or a counter attraction bait used at times of swarming and emergence of the males.

Camponotus compressus, F., attacks *Holcocera*, *Eublemma*, and Chalcid larvae where exposed.

Camponotus sp., near *varians*, picks up crawling lac larvae and injured lac insects.

Meranoplus bicolor, Guér., picks up crawling lac larvae and males.

Solenopsis geminata rufa, Jer., attacks *Eublemma* and *Holcocera* larvae, but picks up crawling lac larvae, males and lac pupae.

Iridomyrmex anceps, Rog., attacks injured *Eublemma* and *Holcocera* larvae and uninjured *Eublemma* larvae cautiously, but picks up crawling lac larvae.

Cremastogaster dohrni, Mayr, picks up crawling larvae and males.

Coleoptera.—The larvae, pupae, and imagines of many kinds of beetles are found in dead lac cells, and it seems probable that they are scavengers. Their function is being investigated, together with their reported damage to stored lac. *Tribolium* sp., *Silvanopsis* sp. and a Dermestid are fairly commonly found.

Pests of Host-trees.

A number of tree pest are found attacking lac host-trees, and in many cases their attacks tend to be the more severe as a result of lack of vitality on the part of the tree owing to the presence of *L. lacca*. Research is being continued as regards their life-histories and natural enemies, and control methods are being devised. The following species are mentioned on account of their prevalence.

Aspidiotus sp. (Coccidae). A serious pest on *Zizyphus jujuba*, *Acacia catechu*, and less often *Schleichera trijuga*. As its appearance is periodic, alternative hosts are being searched for. Certain Rosaceae have been found infested. Control consists in cutting and burning badly infested shoots and spraying with lime and sulphur.

Leccanium sp. (Coccidae). A pest on *Zizyphus jujuba*, *Acacia catechu*, and the shrub host, *Flamingea congesta*. Lime and sulphur spraying is used as control.

Machaerota planitiae, Dist. (Cercopidae). A pest of *Zizyphus jujuba* and *Z. xylopyra*, causing "die-back." Spraying with 10 per cent. phenyl when the young nymphs are present, prior to building their tubes, has been found effective.

Termes spp. White ants are an important pest, and the damage to young trees is extensive. Watering the roots of affected trees with 10 per cent. phenyl has been found satisfactory.

Hieromantis ioxysta, Meyr. (Tineidae). The larva is a leaf-miner on *Schleichera trijuga*. Spraying with lead arsenate and also phenyl has been found of value.

The nymphs of a cricket live in deep tortuous burrows in the earth, and emerge at night to strip leaves from *Acacia catechu*, *Zizyphus jujuba*, and *Z. xylopyra* to take to their burrows. Digging out is at present the only control measure.



Lac on *Acacia catechu*: on left, a healthy stem; on right, a stem attacked by *Eublemma amabilis*, the galleries of which are indicated by the arrows.

A NEW SPECIES OF *ERYTHRONEURA* (HOMOPTERA, JASSOIDEA)
INJURIOUS TO CASSAVA IN EAST AFRICA.

By W. E. CHINA.

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The following description is based on material received from Dr. H. H. Storey, of the Amani Institute, Tanganyika Territory.

***Erythroneura cassavae*, sp. nov. (fig. 1).**

Colour:—Head bright yellow shading to orange at apex of clypeus and on labium; eyes grey-black; a broad shining brownish-black percurrent stripe down middle of vertex, extending slightly round anterior margin of head to frons, and much broader anteriorly than posteriorly. Pronotum shining black with a trace of whitish pruinosity giving a bluish sheen; a narrow transverse yellow band along anterior margin behind each eye, extending outwardly to and along lateral margins,

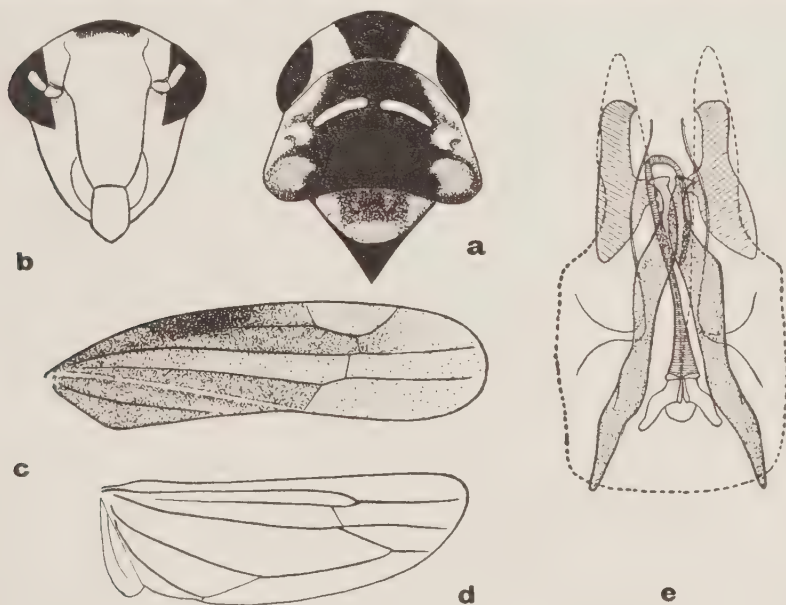


Fig. 1. *Erythroneura cassavae*, sp. n.: a, head, pronotum, and scutellum; b, face; c, tegmen; d, wing; e, male genitalia.

a pair of narrow arcuate whitish spots on anterior disc between eyes and almost meeting in middle line, an impressed whitish spot on each side beyond outer end of arcuate spot and fusing externally with the yellow lateral border, and a large obscure yellowish rounded spot in each of the basal lateral angles. Propleura yellow. Scutellum shining black, covered with whitish pruinosity over impressed region of disc, giving a bluish sheen. Meso- and meta-pleura yellow shading to dark brown towards acetabula, the meso- and meta-sterna dark brown. Tegmina semi-hyaline, sometimes powdered with white pruinosity, which gives them a bluish sheen; the suprabrachial area and the first, third and fourth apical areas slightly infumate, the remainder infusate; the costal plaque dark brown, veins brown. Wings

hyaline, somewhat infumate, the veins (except cross-vein between second and third longitudinal veins) brown. Legs pale yellow, the anterior tibiae and tarsi and the intermediate tarsi infusate. Abdomen entirely black, with very fine white pruinosity giving a bluish sheen.

Structure:—Ocelli absent; head narrower than pronotum across humeral angles (37 : 41), seen from above less than half as long in middle as wide between eyes (10 : 23), only slightly longer than length at eye (10 : 8). Face 2.75 times as long as wide between antennae (44 : 16), the frons more than three times as long as clypeus (33 : 9), which is apically angulate. Pronotum rather more than half as long as wide across humeral angles (24 : 41). Scutellum triangular, rather wider at base than length of side; disc transversally depressed. Tegmina extending well beyond apex of abdomen, venation normal. Subgenital plates (♂) strongly emarginate at sides; genital appendages figured. Last ventrite in female with its posterior margin angulate, its apex slightly rounded. Ovipositor extending beyond apex of abdomen. Total length 2.8 mm.

TANGANYIKA TERRITORY : Amani, 1 ♂, 5 ♀♀ on cassava (*Manihot*), Nov. 1929 (*H. H. Storey*).

Differs from all Ethiopian species of *Erythroneura* recorded by Naudé (S. African Dept. Agric., Ent. Mem. 4, pp. 97-98, 1926), except *Erythroneura elegia*, Cogan, in the presence of a large brown spot on yellow vertex. Differs from *E. elegia* in its smaller size, entirely black abdomen and the yellow clypeus.

This is the twelfth African species of *Erythroneura* to be described. *E. nuchalis*, Jac., recorded from Mt. Kilimanjaro probably does not belong to this genus.

THE BREEDING IN NATURE OF *PHLEBOTOMUS ARGENTIPES*, ANN. & BRUN.

By Lieut.-Colonel H. E. SHORTT, F.Z.S., I.M.S.,
Assistant-Surgeon R. O. A. SMITH, D.T.M., I.M.D.,
and
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The importance that has attached to the genus *Phlebotomus* in connection with its rôle as a possible vector of infections with various members of the family TRYPANOSOMIDAE has led in recent years to an intensive study of this genus. This study has been pursued chiefly in two directions, *viz.*, the differentiation of species and the possible rôle played by some of these in the transmission of trypanosome infections.

As regards the latter line of research most attention has been directed to an anatomical study of a few species of *Phlebotomus* and the relationship of particular flagellates of the genus *Leishmania* to the cavities and organs of the flies concerned. The possibility that these researches may lead eventually to the incrimination of certain species of *Phlebotomus* as vectors of trypanosome infections in man or animals necessitates a knowledge of the breeding habits of the genus, since, as in the case of other harmful insects, it is probable that the immature stages will be the most vulnerable to attack should preventive measures become necessary.

Until the work of Young, Richmond & Brendish (Ind. J. Med. Res., xiii, April, 1926, p. 961) only cursory findings of breeding-places of *Phlebotomus* had been made. These workers, however, by the application of flotation methods to the search for *Phlebotomus* larvae were successful in finding large numbers of breeding-places, and were able thereby to establish, for the species they were concerned with, the natural requirements, as regards site and soil composition, necessary for the breeding of these species. It is with the application of these methods to the species *Phlebotomus argentipes* that the present description is concerned.

Materials and Technique.

The fluid of high specific gravity used for flotation of larvae was that recommended by Young, Richmond & Brendish, *viz.*, a saturated solution of white sugar.

The routine procedure adopted was as follows:—

1. The samples of earth and organic debris to be examined are collected in rectangular biscuit tins, the average sample weighing about 3 lb.
2. On arrival at the laboratory each sample is repeatedly washed in water in a large enamel hand-basin, the turbid liquid being passed successively through brass sieves of 10 and 20 meshes to the inch. This is repeated till the residue in the basin consists only of coarse sand and pebbles and this, with the material left on the sieves, is rejected.
3. The fluid, which now consists of muddy water without large particles, is next passed successively through similar sieves of 40 and 60 meshes to the inch, clean water in addition being passed through the sieves, if necessary, to complete the filtration.
4. The residue on the 40 and 60 mesh sieves now forms the material for examination.

5. This is washed with water into a white enamel photographic dish, thoroughly agitated to dislodge larvae adherent to floating débris and a short interval for settling allowed.

6. The supernatant fluid is now syphoned off and a saturated solution of white sugar added to the deposit.

7. This is well stirred in the sugar solution and the whole allowed to stand for a few minutes.

8. All insect larvae, Acarines, Nematodes, etc., are found floating on the surface of the fluid, and from among them the *Phlebotomus* larvae and pupae are readily detected by a hand lens. To facilitate the search, currents are set up on the surface of the liquid by gentle blowing upon it. In this way the floating objects pass slowly under the lens. The ova are not found, as they escape even through the 60-mesh sieve. In a successful sample forty or more larvae of *P. argentipes* may be found.

Sites selected as Breeding-places.

The question as to whether *P. argentipes* is found apart from human habitations has so far not been gone into, and our searches for breeding-places have therefore been confined to the immediate surroundings of houses in town and village. As the result of experience gained it is now possible for us, by a mere inspection of the surroundings, to indicate with a considerable degree of certainty the breeding-sites in any locality where the adult flies are found. The desiderata for suitable breeding-places may be considered under three chief heads, which will be briefly commented on below.

The presence in the soil of organic débris.—This is a *sine quâ non*, as the organic material is necessary for the food of the larvae. As a matter of actual fact, nearly all natural soil near dwelling-houses fulfils this condition, and only rarely would the organic content be below that necessary for the continuance of breeding.

Protection of the breeding-place from the elements.—For successful breeding the site must be reasonably sheltered from chances of flooding by rain or other water, and from thorough desiccation by a hot sun or dry wind.

Nature of the soil.—The soil must be sufficiently loose to admit of the burrowing in it of the larvae in their search for food. This does not necessarily imply that the soil must be very moist. On the surface it may be quite dry, hard and caked; but this condition is usually accompanied by the production of surface cracks admitting air and moisture to the interior soil. The hard outer surface also prevents too rapid desiccation of the interior by evaporation in warm dry weather.

As regards the actual situations in and around dwellings which fulfil all these conditions for the continuance of successful breeding by *P. argentipes*, and where breeding has actually been found in progress, mention may be made of the commonest. These are:—

1. The plinths on which most houses in Assam are constructed. The material of these plinths usually consists of a mixture of clay and cow-dung dried by the sun. The plinth projects beyond the walls of the house, and it is in the projecting portion, protected to some extent from rain and sun by the projecting eaves of the house, that breeding-places are most frequently encountered. The side most protected from the sun is usually the most fruitful for search.

2. The corners inside the rooms of the house and the angles formed by the walls and floor. These situations correspond to those on the outer side of the walls, as the floor is merely the part of the plinth within the walls of the house, and its composition is uniform throughout.

3. Similar situations to those described in the last two sections, but in cattle-sheds. In this case the plinth may be less evident or even absent, but the immediate neighbourhood of the bamboo walls of which the sheds are constructed presents the same conditions of shelter and moisture necessary for breeding-places.

4. On the sheltered side of and underneath any heaps of miscellaneous débris lying near the houses. These heaps may be piled logs of wood, old bricks, or, in fact, anything providing adequate shelter for breeding-places.

We have not yet definitely ascertained the depth of soil to which breeding is restricted, and experiments to this end are now in progress.

Conditions present during the Cold Weather.

In Gauhati, Assam, where our work is being carried on, we find that during the period between the second half of December and the first half of February, inclusive, *Phlebotomus argentipes* is very rarely found in nature. We have succeeded, however, in obtaining larvae from known breeding-sites during this "off" season, and there is no doubt that it is chiefly in the larval stage that the fly exists during the coldest months of the year. The larvae found at this season generally show food in the intestine, indicating that there is no true hibernation in the larval stage, but merely a slowing down of the rate of development.

NOTES ON *ARGAS BRUMPTI* (ACARINA). *W.*

By W. RUTLEDGE, B.A. (Cantab.),

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Argas brumpti was first described by Neumann, in 1907 from specimens taken by Brumpt in Somaliland (Ogaden), and has since been found to occur also in British East Africa (Kitui) and the Sudan (Erkowit, Gebelein and Nuba Mountains). In the nymphal and adult stages it has a wide range of hosts, including man, but in the larval stage is far less catholic in its tastes. Cunliffe,¹ in 1913, failed to induce the larvae to feed on a domestic fowl; King,² in 1915, having similarly failed to rear them on domestic fowls, sparrows, pigeons, doves and bats, found that they would attach themselves readily to the loose skin on the head and neck of the guinea-fowl, *Numida meleagris*, and engorge. Larvae so fed were reared to maturity. It was believed that the guinea-fowl was possibly the usual host of *A. brumpti* in the larval stage, but the examination of numbers of guinea-fowl shot in districts in which this tick occurs yielded no confirmatory evidence.

Early in 1928, when stationed in the Nuba Mountains, the writer noticed that the rock-lizard, *Agama colonorum*, Daud., was usually infested with larval ticks; these larvae were determined as *A. brumpti*, and subsequently this determination was confirmed when specimens had been reared to the nymphal stages. This lizard is a common species in that locality, and almost every specimen examined in March bore two or three ticks, and occasionally as many as ten would be found on a single lizard, attached to the loose skin of the head and neck. Later in the year the lizards seemed free from tick larvae. It appears highly probable that the normal host of this tick in the larval stage is *Agama colonorum* and possibly allied species of lizards.

As an instance of longevity in *A. brumpti* it may be worth placing on record that a female specimen taken by King at Erkowit, in August 1918, is still alive in Khartoum at the time of writing (April 1930). She has thus lived in captivity for 11 years and 8 months, and it should be noted that she was adult when taken.

References.

1. CUNLIFFE, N. *Parasitology*, Cambridge, vi, 1913, pp. 379-381.
 2. KING, H. H. *Bull. Ent. Res.*, vi, 1915, pp. 191-193.
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NEW BRACONIDAE AND OTHER NOTES.

By D. S. WILKINSON,

Entomologist, Imperial Institute of Entomology.

BRACONIDAE.

Spinaria spinator, Guérin, 1830.

MALAYA: Teluk Anson, 1 ♀, iii.1923 (*G. H. Corbett*), 3 ♀♀, 1 ♂, 18.iv.1930; Serdang, 1 ♀, 1 ♂, 17.i.1925 (*G. H. Corbett*); Kuala Lumpur, 1 ♀, 10.vii.1928 (*G. H. Corbett & B. A. R. Gater*).

Host. The three more recent series were bred from larvae of the Limacodid moth, *Setora nitens*, Walk.

Fornicia, Brullé.

At the time that he wrote his paper on *Fornicia* and *Odontoformica*, and described four new species in the latter (*Phil. Journ. Sci.*, xl, 1929, pp. 233–237), Cushman had, presumably, not seen my notes on this question (*Bull. Ent. Res.*, xix, 1928, p. 261). I am still of the opinion, and so far as I am aware so is Dr. Muesebeck, that these two genera are synonymous; consequently Cushman's species (*Odontoformica borneanus*, *O. moronis*, *O. penang*, and *O. tagalog*) should be referred to *Fornicia*.

Fornicia africana, sp. n.

♀. Black; femora, tibiae, and tarsi of the four anterior legs, the hind femora, hind tibiae (except basal sixth), red, the extreme apices of the hind femora slightly darkened; spurs of the four posterior tibiae, apical segments of the palpi, basal sixth of the hind tibiae, pale to white; tegulae, and all veins at extreme base of wings, testaceous to colourless; stigma dark brown to black, majority of remaining veins dark brown.

♀. *Head*: face with minute punctation, the clypeus smooth; vertex and occiput smooth with only minute and sparse punctures; flagellum shorter than combined length of head, thorax, and abdomen. *Thorax*: mesonotum with an obsolete median longitudinal carina, narrowly along each side of which the integument is reticulate; the lines of the notauli indicated by broad reticulate bands, which latter together with the median line converge posteriorly and run into a strongly reticulate area that occupies the majority of the posterior third of the mesonotum; integument above tegulae reticulate; mesonotum otherwise with strong punctation save at extreme apex narrowly across in front of the strongly crenulate basal sulcus of the scutellum, where it is entirely smooth; scutellum triangular, convex, strongly reticulate, shortly produced apically into a single, obliquely raised, truncated prominence, which in profile is very thin; metanotum medianly with a prominent spinelike process; propodeon much as in *F. ceylonica*, Wilkn. *Wings* very like those of *F. ceylonica*, but with the stigma relatively rather broader and the transverse cubital relatively rather shorter. *Legs*: hind coxae on outer faces with close, fairly strong punctures, not or hardly reticulately punctate; the longer hind tibial spur rather shorter than three-fifths, and the shorter spur two-fifths, the length of the basal joint of the hind tarsus. *Abdomen*: very like that of *F. ceylonica* except that the raised median longitudinal area definitely extends to apex of 3rd tergite.

Length, 4.5 mm.

SOUTHERN RHODESIA: Hunter's Road, 3 ♀♀, iii.1930 (*A. Cuthbertson*).

Type deposited in the British Museum.

Host. A Limacodid attacking coffee.

This species is the first of this group to be described from the Ethiopian region. It will not run in Cushman's key (Phil. Journ. Sci., xl, 1929, p. 234) because it possesses both the unidentate scutellum and the spine on the metanotum; and on this account also, *inter alia*, it differs from *F. ceylonica*.

Apanteles, Foerster.

Apanteles, Foerster, Verh. naturh. Ver. preuss. Rheinl., xix, 1862, p. 245.

Allapanteles, Brèthes, An. Mus. Nac. Buenos Aires, xxvii, 1915, p. 404.

Although the single species upon which *Allapanteles* was erected (namely, *A. eccidiptae*, Brèthes, which was described as a new species at the same time, and which now should be referred to *Apanteles*) is not known to me, it is quite clear from the short description of the genus that *Allapanteles* differs from *Apanteles* no more than the other untenable genera that Muesebeck and myself have already sunk. Brèthes' description is as follows:—*Ut Apanteles, etc., conformatus, sed abdomine segmento 2° polito sicut segmenta sequentes distinctus.*

Apanteles insolens, sp. n.

♀. Black; scape, labrum, prothorax, mesonotum, mesopleurae above anteriorly, tegulae, occasionally disk of scutellum along sides, all legs (except hind tarsi, which are darkened slightly), majority of pleurites and sternites, red testaceous; palpi and tibial spurs pale; antennae dark brown; wings slightly and evenly infumated, with veins and stigma brown.

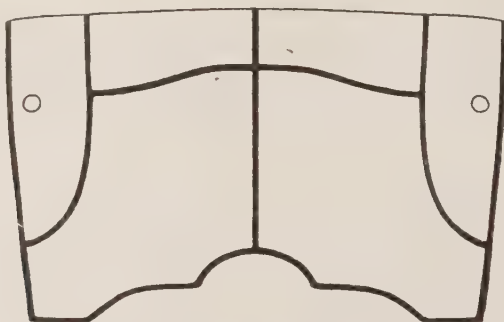


Fig. 1. *Apanteles insolens*, sp. n.: semi-diagrammatic drawing of the areation of the propodeon.

♂. Agrees with above description of colour of female except that on the whole it is rather darker, as follows:—Prothorax and hind tarsi decidedly darkened; hind coxae darkened to black in basal third to half; mesonotum invariably with narrow median longitudinal darkening, occasionally almost entirely darkened to black.

♀♂. *Head* throughout with close, strong, but rather shallow punctation (degree 4); face with a weak median longitudinal keel; clypeus differentiated from face; facial depressions rather nearer to apex of clypeus than to eyes; posterior ocelli rather nearer to each other than to eyes. *Thorax*: mesonotum with regular, strong (degree 4), close, rather shallow punctation; disk of scutellum punctate (degree 3); propodeon, apart from major carination (fig. 1), with certain indefinite sculpture beyond costulae, otherwise smooth. *Wings*: breadth of stigma 1.4 times length of transverse cubital, this latter equal to, and strongly angled with, 1st abscissa of radial; recurrent and pigmented portion of 2nd abscissa of cubital

of equal length, but variable so that both, or one or the other, may be shorter than or equal to transverse cubital; upper portion of basal vein equal to apical portion of 1st abscissa of cubital, about half length of recurrent; stigma shorter than metacarp; 2nd abscissa of radial present, punctiform or evenly occasionally with length nearly twice its breadth. *Legs*: hind coxae on outer faces smooth in at least upper half, with some punctation basally above; the longer hind tibial spur half, and the shorter spur two-fifths the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite slightly turned over and down, in basal half smooth and excavated and with in addition a narrow median longitudinal excavation, in apical half rugulose, the median length twice basal breadth, this latter twice apical breadth, the sides in at least basal half parallel then roundly converging to the truncated apex; 2nd tergite with a smooth, rounded, quadrate, median area extending from base to apex, laterally to which the tergite is depressed, with the lateral sulci widely divergent and turned upward, the median length of the tergite equal to the breadth of the rounded area, which is equal to the breadth of apex of 1st tergite; 3rd tergite with only usual minute punctation, its median length twice that of 2nd tergite; ovipositor sheaths stout, about equal in length to basal joint of hind tarsus.

Length, 2.5 mm.

SOUTH AFRICA: Mossel Bay, Cape Province, 6 ♀♀, 5 ♂♂, x.1921, 1-14.xi.1921, 18-30.xi.1921, xii.1921 (*R. E. Turner*).

Type in the British Museum.

Host unknown.

Cocoons unknown.

This is an interesting species, being quite distinct from anything that I have seen on account of the carination of its propodeon; the red testaceous coloration of the mesonotum and prothorax also is unusual.

***Apanteles coffea*, sp. n.**

♀. Black; the four anterior legs (except their coxae), the hind trochanters and trochantines, hind femora, basal two-thirds of hind tibiae, abdomen entirely (except for black lateral margins of 1st tergite and darkened apices of apical tergites), and ovipositor, red testaceous; all coxae reddened at extreme apex, particularly hind coxae below; stigma dark brown to black, with a strong cloud occupying basal fourth; majority of remaining veins brown; palpi and tibial spurs pale.

♂. Agrees with the colour description of female except as follows:—Middle tibiae and tarsi slightly darkened; basal half to two-thirds of hind tibiae red testaceous; abdomen with tergum black, and sternum more or less testaceous; majority of remaining wing-veins colourless.

♀. *Head* with close shallow punctation; clypeus not differentiated; facial depressions nearer to apex of clypeus than to eyes; posterior ocelli decidedly nearer to each other than to eyes. *Thorax*: mesonotum with strong (degree 4), fairly close, but definitely separated, punctation; disc of scutellum smooth and shining, with some punctation (degree 3 and 2); propodeon almost rugoso-punctate basally as far as costulae, indefinitely sculptured in areola, smooth beyond costulae, the carinae of areola and costulae well marked, the areola at base closed and acutely angled, the carinae continuing to base of propodeon as a median longitudinal carina. *Wings*: 1st abscissa of radial and transverse cubital more or less evenly rounded or at least their point of junction hard to determine, their combined length 1.75 times breadth of stigma, this latter hardly greater than length of recurrent, which is 1.5 times length of apical portion of 1st abscissa of cubital; metacarp considerably longer than stigma. *Legs*: hind coxae with some punctation (degree 3-4) above and basally

above, on outer faces entirely smooth; the longer hind tibial spur half, and the shorter spur about two-sevenths, the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite shining, smooth (save possibly along lateral margins), rather weakly turned over and down, weakly excavate basally, medianly with a weak, smooth tumescence, with median length 1.58 times apical breadth (38:24), the lateral margins parallel or very slightly bisinuate, the apex truncate or very slightly emarginate, the apical angles not rounded; 2nd (save for weak lateral sulci) and succeeding tergites smooth and shining; 2nd suture almost entirely wanting, only just visible; median length of 3rd tergite 1.44 times that of 2nd tergite (13:9); ovipositor sheaths considerably longer than hind tarsus.

♂. Agrees well enough with above description of female except as follows:—*Legs*: the shorter hind tibial spur not less than one-third the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite with median length twice apical breadth, the sides very weakly bisinuate and slightly converging to apex; 2nd suture entirely wanting.

Length: ♀, 3.25 mm., ♂, 2.5 mm.

UGANDA: Kampala, 1 ♀ (*type*), 5 ♂♂, 15.vi.1929 (*H. Hargreaves*), 1 ♀, 24.ii.1927 (*G. L. R. Hancock*), 5 ♀♀, 15.iii.1930 (*H. Hargreaves*), 1 ♀, 3.iv.1930 (*G. L. R. Hancock*).

Type deposited in the British Museum.

Host. The series dated 1929 is labelled "*ex* probably *Argyroproctus batrachopa*." Mr. Hancock tells me, however, that this *Apanteles* was bred from a larva boring into coffee berries, that this larva was probably the Tortricid, *Argyroproctus* (= *Enarmonia*) *batrachopa*, Meyr., but that it was possibly the larva of another Lepidopterous borer of coffee, namely the Pyralid, *Thliptoceras octoguttalis*, Felder, from which latter, feeding in berries of *Tricolybia* sp. (Rubiaceae), were bred the five females dated 15.iii.1930 and the single female dated 3.iv.1930.

Cocoons white.

On account of the coloration of its legs, scape and tegulae, its unsculptured 2nd tergite, and the distinct cloud in basal fourth of stigma, *A. coffea* runs in my new key to *diparopsidis*, Lyle. These two species are quite distinct, however: I have separated them in the key by the coloration of the abdomen and the sculpture of the 1st tergite.

***Apanteles earterus*, sp. n.**

♀♂. Black; the forelegs (except their coxae), middle femora towards apex, apical half of middle tibiae, middle tarsi, basal fourth or sixth of hind tibiae, the costal veins of the forewing, testaceous or red testaceous; palpi and hind tibial spurs pale; stigma hyaline with a narrow border of pigmentation—the costal border dark brown (as is the metacarp), with the inner borders brown to dark brown; majority of remaining veins colourless.

♀. *Head* in the greater part with close, minute, indefinite punctuation; facial depressions nearer to apex of clypeus than to eyes. *Thorax*: mesonotum with strong, regularly and very closely placed punctuation, but entirely devoid of rugosity or of rugose striation; disc of scutellum with some indefinite punctuation; propodeon with the carinae of the areola and the costulae strong, the areola open at base, the propodeon otherwise shining and with only indefinite sculpture. *Wings*: 1st abscissa of the radial in length about equal to the breadth of the stigma, longer than the recurrent, 1.5 times as long as the transverse cubital, this latter about equal to the apical portion of the 1st abscissa of the cubital; metacarp rather longer than stigma. *Legs*: hind coxae on outer faces smooth and shining with only a little minute punctuation, above with minute punctuation; hind tibial spurs subequal, the longer spur half the length of the basal joint of the hind tarsus. *Abdomen*: 1st

tergite shining, slightly turned over and down, basally slightly excavated, medianly with a smooth, weak tumescence, in apical half with a very shallow, smooth, areola-like excavation in the middle and weakly and indefinitely sculptured in the lateral thirds, with median length 1.5 times apical breadth, the basal breadth (except at extreme base) equal to the apical breadth, the sides being more or less parallel (somewhat sinuate), with the apex truncate and straight (possibly very slightly emarginate) and the apical angles about right-angles; 2nd tergite small, with greatest breadth a little greater than basal breadth and three times median length (18:15:6), the lateral sulci very short and the 2nd suture strongly rounded; 3rd tergite 1.66 times as long as the 2nd; 2nd and succeeding tergites smooth save for the usual sparse, minute punctation; 2nd suture obsolete; ovipositor sheaths about as long as the hind tarsi; hypopygium membranously acute.

♂. Agrees with the above description of the female except as follows: *Thorax*: propodeum with the carinae of the areola and the costulae rather weak. *Abdomen*: 1st tergite shining, with slight basal excavation, medianly without tumescence, in apical half with an extremely shallow, indefinite, areola-like excavation in the middle and very weakly and indefinitely sculptured to smooth laterally, with median length rather greater than twice apical breadth, but rather less than twice greatest breadth (22:10:13), the greatest breadth being near base, and the sides straight and regularly (though slightly) converging to the truncate, straight or possibly slightly emarginate apex; 2nd tergite with apical breadth about 1.8 times basal breadth and three times median length, with the lateral sulci not strongly oblique and about as long as the median length; the 2nd suture curved, but definitely not so strongly as in the female.

Length, 2.5 mm.

ANGLO-EGYPTIAN SUDAN: Khartoum, 1 ♀, 19.xii.1929 (*H. W. Bedford*), 1 ♂, 10.xii.1929 (*A. M. Makkawi*); Shendi, 3 ♀♀, 1 ♂, 27.xii.1928, 31.xii.1928 (*H. W. Bedford*), 1 ♀ (*type*), 12.vi.1928, 1 ♂, 21.vi.1928 (*J. W. Cowland*), 3 ♀♀, 1.ii.1929, 6.ii.1929, 9.ii.1929 (*Abdulla Hassan*); Zeidab, 2 ♀♀, 16.i.1929 (*H. W. Bedford*), 1 ♀, 3.vii.1928, 1 ♂, 29.ix.1928 (*J. W. Cowland*); Saadabia, 1 ♀, 22.xii.1928 (*H. W. Bedford*); Mikallab, 1 ♂, 29.vi.1928 (*J. W. Cowland*); Delami, Nuba Mountains, 1 ♂, 1.viii.1927 (*W. Rutledge*).

Type deposited in the British Museum.

Host. Of these specimens some are labelled as bred from *Earias insulana*, Boisd., some from *Diparopsis castanea*, Hmps., others from young larvae of *Diparopsis castanea*. Again, many were bred from bolls of *Abutilon* sp., and others from cotton bolls.

Mr. Bedford tells me that this species parasitises the fully-grown larvae of *Earias insulana* on both *Abutilon* and cotton, and half-grown larvae of *Diparopsis castanea* on cotton.

Cocoons white.

I had originally confused *Apanteles earterus* with *A. diparopsidis*, Lyle; and although very like this species, it is easily separable by means of its entirely darkened hind femora, by its hind tibiae testaceous only at base, by its very marked, discally hyaline stigma, and by its more densely placed mesonotal punctation and smoother 1st tergite. *A. diparopsidis* was originally described from *Diparopsis castanea*, and has since been recorded (Wilkinson, Bull. Ent. Res., xviii, 1928, p. 394) from *Platyedra erebodoxa*, Meyr.

In my new key, *earterus* comes close to *taragamae*, Vier., and *baoris*, sp. n., from which it is distinct if only on the coloration of the hind tibiae and on the nature of the mesonotal punctation.

Apanteles baoris, sp. n.

♀♂. Black; fore and middle legs (except coxae, and often middle femora in basal half), hind tibiae (except at apex), red testaceous; hind femora, hind tarsi, and apex of hind tibiae, darkened; palpi and hind tibial spurs pale; stigma hyaline with a narrow border of pigmentation, this border, the costal veins, and metacarp, brown, remaining veins virtually colourless.

♀. *Head* in the greater part with minute punctation; facial depressions nearer to apex of clypeus than to eyes; posterior ocelli nearer to each other than to eyes. *Thorax*: mesonotum, particularly in posterior half, polished and with punctures (degree 3) widely separated, without traces of striation or rugosity; disc of scutellum with minute punctation; propodeon indefinitely sculptured and rather dull from base to costulae, smooth and shining beyond costulae and in areola, the carinae of the areola and costulae well marked. *Wings*: the 1st abscissa of the radial and the transverse cubital evenly rounded with their point of junction indeterminable, their combined length 1.5 times the breadth of the stigma, 1.8 times the length of the recurrent; apical portion of 1st abscissa of cubital shorter than the recurrent, twice the length of the pigmented portion of the 2nd cubital, this latter equal to upper portion of basal vein; stigma shorter than metacarp. *Legs*: hind coxae with sparse, minute punctation; the longer hind tibial spur barely half, and the shorter spur less than two-fifths, the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite slightly turned over and down, basally slightly excavated, medianly slightly tumescent, indefinitely sculptured to weakly rugose in the apical two-thirds, in the apical third more or less smooth and shining in the middle, with the sides virtually parallel, the apex emarginate, and with median length twice apical breadth; 2nd tergite smooth, its median length half basal breadth, its apex evenly and rather strongly rounded, the well-marked lateral sulci shorter than median length; 3rd tergite smooth (as all succeeding tergites), rather longer than 2nd; 2nd suture obsolete; ovipositor sheaths rather longer than hind tibiae; hypopygium membranously acute.

♂. Agrees well enough with the above description of the female except as follows: *Abdomen*: 1st tergite if anything slightly narrowed at apex; 2nd tergite with median length less than basal breadth and just longer than the lateral sulci (7:9:6 in the smaller specimens).

Length, 1.75–2 mm.

MALAYA: Gunong-Semanggol, Perak Province, 15 ♀♀ (one the *type*), 2 ♂♂, 3.i.1930, 5 ♀♀, 14.ii.1930 (*H. T. Pagden*); Kuang, 7 ♀♀, 4 ♂♂, 19.ix.1928, 2 ♀♀, 1 ♂, 26.ix.1928 (*G. H. Corbett*); Kuala Lumpur, 12 ♀♀, and 1 of sex indeterminable through damage, undated (*G. H. Corbett*).

Type deposited in the British Museum.

Host. The series from which the type is selected, namely, that dated 3.i.1930, is labelled as having been bred from larvae of the Hesperiid butterfly, *Parnara (Baoris) mathias*, Moore; the series dated 14.ii.1930 from an Hesperiid on *Oryza*; that dated 19.ix.1928 from an "Hesperiid on *Oryza*, probably *Parnara mathias*"; that dated 26.ix.1928 from *Parnara (Baoris) bada*, Moore, on *Oryza sativa*; and the undated series as a parasite on *Parnara bada*.

Cocoons. The series dated 3.i.1930 was bred from a white gregarious mass 15 mm. long, by 4, by 4 mm.

This species runs in my new key to *taragamae*, Vier., from which it may be easily separated by means of the smooth mesonotum with its widely spaced punctation.

Certain quite considerable variation is noticeable in the shape of the 1st tergite of the females. In the series dated 19.ix.1928, for example, where the specimens are rather bigger than those in the series from which the type is selected, the female 1st

tergite is relatively much broader, the length being only 1.5 times as great as the breadth. This increased relative breadth of the 1st tergite affects to some extent also the general shape of the 2nd, giving it the appearance of also being relatively broader. I do not, however, consider that these differences can be taken, in this instance, to be of specific value, particularly since the specimens concerned otherwise agree absolutely both in general facies, which is important, and in all other of the minutest details of colour and structure, and sufficiently with regard to locality and host.

***Apanteles ruficollis*, Cam.**

Xanthomicrogaster ruficollis, Cameron, Jl. R. Agric. Soc. Demerara, i, 1911, p. 325.

A species described from 4 ♀♀, 4 ♂♂, all mounted on one card, from British Guiana.

Type in the British Museum.

Host. The specimens were recorded by Cameron to have been bred from the Pyralid moth, *Zinckenia* (now *Hymenia*) *fascialis*, Cram., but they are not labelled to this effect.

A. ruficollis runs in my key to *detrectans* or *cajani*; it is, however, very distinct from any species known to me in this subgroup on account of the red testaceous mesonotum of the females, and the hyaline stigma.

I have written in this paper, under *Microgaster fortipes* (p. 284), some notes with regard to the genus *Xanthomicrogaster*.

***Apanteles thurberiae*, Muesebeck (1920).**

TRINIDAD: Cotton Research Station, 1 ♀, 2 ♂♂, iii. 1930 (*Dr. J. G. Myers*).

Host. This series was bred by Dr. Myers as a solitary parasite of nearly full-grown larvae of *Platyedra gossypiella*, Saund. *A. thurberiae* was originally described from Arizona as a solitary parasite of bollworms in *Thurberia thespesioides* (Malvaceae).

***Microgaster botydis*, sp. n.**

♀. Black; scape on inside, mouth-parts, front legs entirely, wing insertions immediately beyond tegulae, middle coxae, middle trochanters and trochantines, middle tibiae basally, basal third or half of hind coxae, all tibial spurs, basal third or half and lateral membranous margins of 1st tergite, basal ventrites completely, remaining ventrites to some extent, yellow testaceous to red testaceous; middle femora darkened; middle tibiae apically, and middle tarsi, slightly darkened; prosternum completely black, particoloured, or completely red testaceous; ovipositor red; stigma and wing veins dark brown to black; wings slightly, but very definitely, and evenly infumated throughout.

♀. *Head*: face striato-punctate, approaching rugoso-punctate, more coarsely so down sides, with a faint median longitudinal keel; clypeus coarsely punctate (degree 5), differentiated; facial depressions nearer to eyes than to apex of clypeus; labrum large; cheeks coarsely striate; frons and vertex with indefinite punctation; posterior ocelli possibly rather nearer to each other than to eyes. *Thorax*: mesonotum with evenly and rather widely spaced strong punctation (degree 4), anteriorly the punctures stronger (degree 5) and closer, in middle in posterior third or half minute (degree 2); disc of scutellum with evenly and widely spaced minute punctation (degree 2); propodeon smooth and shining, with a strong median longitudinal carina, which is strongly crenulate down the sides. *Wings*: 1st abscissa of radial 1.5 times as long as breadth of stigma, 1.3 times as long as 1st

transverse cubital, this latter, which is slightly bisinuate, receiving the very short, hyaline, 2nd transverse cubital at or slightly above its centre, the 2nd cubital cell thus small and triangular; apical portion of 1st abscissa of cubital shorter than recurrent, longer than the combined length of pigmented portions of 2nd and 3rd abscissae of cubital, which is about equal to or rather longer than upper portion of basal vein; stigma shorter than metacarp. *Legs*: hind coxae in upper half smooth and highly polished; the longer hind tibial spur two-thirds, and the shorter spur one-third, the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite with basal two-thirds smooth and shining and evenly excavated, the apical third turned over and down, and strongly and closely punctate (degree 4-5), except extreme apex which is entirely smooth, with median length five times apical breadth and 1.66 times greatest breadth, which latter is at apex of basal fifth and whence the straight sides converge regularly to the truncate apex; 2nd tergite with only minute punctuation, its shape much as in *M. psarae*, Wilkn., the median length a little greater than apical breadth of 1st tergite; 3rd and succeeding tergites with only minute punctuation; ovipositor sheaths large, about as long as hind femora.

Length, 4 mm.

SUMATRA: Deli Experimental Station, 4 ♀♀, 12.xii.1927 (*type*), 3.xii.1927, xii.1927.

Type deposited in the British Museum.

Host. The specimens are recorded by the Deli Experimental Station as "*ex Botys marginalis*" on *Ipomaea* sp. and *Spilanthus acmella*. As the author of this species was not given, and as no species *marginalis* is now referred to the generic name *Botys*, it is possible, Mr. W. H. T. Tams informs me, that the host may be the Pyralid, *Psara marginalis*, Warren, or *Pycnarmon marginalis*, Snellen.

Cocoons unknown.

Microgaster botydis will not run in my key to the Indo-Australian and Ethiopian species (Trans. Ent. Soc. London, 1929, p. 99) on account of its testaceous four anterior coxae in combination with its black hind femora. Apart, however, from colour characters, characters that in this instance are, even by themselves, entirely satisfactory, the nearest allies to this new species are *M. psarae*, Wilkn., and *M. apo*, Wilkn. From this latter *M. botydis* is immediately separable on account of the strong punctuation of its mesonotum. *M. psarae* is much nearer: but the new species has its 1st tergite considerably more elongate, thus more closely resembling *M. apo*, while in addition its much longer 1st transverse cubital and shorter 2nd transverse cubital make the 2nd cubital cell of quite a different shape.

Microgaster austrina, Wilkinson (1929).

UGANDA: Kampala, 9 ♀♀, 4 ♂♂, 17.ix.1929 (*G. L. R. Hancock*).

Host. This series was bred from a larva in a maize cob.

Cocoons white.

This species was originally described from 2 ♀♀ only, from South Africa, from captured material, and the present series is a welcome addition to the collections. The male was not previously known; it differs from the female, apart from usual sexual differences, apparently only in the antennae, which are elongate, being as long as, or longer than, the body.

Microgaster tomentosae, sp. n.

♀. Black; scape, flagellum in basal half, tegulae, legs (except as follows), abdomen (except possibly towards apex, and the ovipositor sheaths), the costal veins and the majority of the veins in the basal half of both wings, red testaceous; stigma,

apical two-fifths of hind tibiae, dark brown to black; hind tarsi slightly darkened; palpi and hind tibial spurs pale; metacarp, radial vein, and the veins of the areolet brown; wings slightly infumated.

♀. *Head*: face with strong and fairly close punctation and striation; frons and vertex with weak, but definitely present, transverse striae; facial depressions nearer to apex of clypeus than to eyes; posterior ocelli nearer to each other than to eyes; antennae rather short and stout. *Thorax*: mesonotum with strong, separated punctation and certain striation; disc of scutellum with some indefinite punctures; mesopleural sulcus obsolete; propodeon in basal half strongly punctate, apically

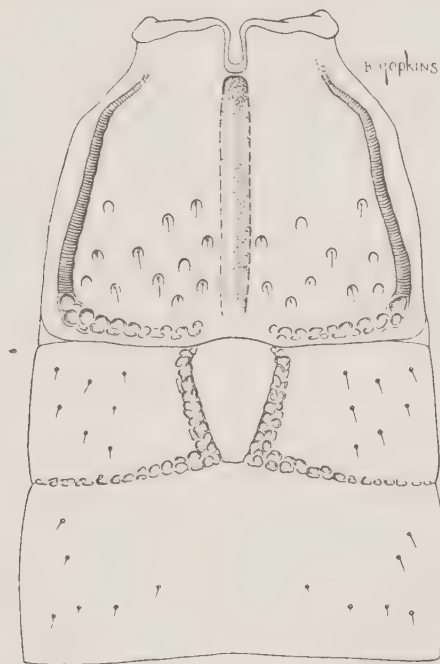


Fig. 2. *Microgaster tomentosae*, sp. n.: 1st, 2nd, and 3rd tergites.

more or less smooth, with a strong median longitudinal carina throughout its length. *Wings*: the recurrent, the 1st transverse cubital, and the 2nd abscissa of the cubital equal in length, just shorter than the 1st abscissa of the radial, just longer than the apical portion of the 1st abscissa of the cubital, this latter in length half the breadth of the stigma; the areolet 4-sided, the hyaline 2nd transverse cubital, and the 2nd abscissa of the radial more or less equal, punctiform, their combined length just less than the upper portion of the basal vein; stigma and metacarp of equal length. *Legs*: hind coxae above and towards apex with strong punctation, on outer faces highly polished and smooth save for some scattered punctures; the longer hind tibial spur four-fifths, and the shorter spur half, the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite (fig. 2) with the apical third slightly turned over and down and with some indefinite punctation, otherwise smooth save for a well-marked, median, longitudinal excavation; 2nd tergite (fig. 2) smooth save for converging median sulci, which are as strong as the 2nd suture; 3rd and succeeding tergites entirely smooth; ovipositor sheaths very short.

Length, 2.5 mm.

INDIA : Dehra Dun, United Provinces, apparently 6 ♀♀, 4.x.1929 (S. N. Chatterjee).

Type deposited in the British Museum.

Host. Recorded by Mr. Gardner to have been bred from an unidentified Pyralid moth defoliating *Terminalia tomentosa*.

Cocoons unknown.

This striking new species runs in my key and is very close to *austrina*, Wilkn., from which, however, it may be easily separated by the coloration of its abdomen and hind coxae ; in addition, the hind coxae are very considerably smoother than in this South African species.

Microgaster fortipes, Cam.

Xanthomicrogaster fortipes, Cameron, Jl. R. Agric. Soc. Demerara, i, 1911, p. 325.

A species described, from apparently a single female, from British Guiana.

Type in the British Museum.

Host unknown.

Cocoons unknown.

The genus *Xanthomicrogaster* was erected by Cameron for the reception of two new species, *fortipes* and *ruficollis*, and the genotype was later designated by Viereck as *fortipes* (Bull. U.S. Nat. Mus., lxxxiii, 1914, p. 153). I have examined the types of both the above species, and have found that *fortipes* is clearly a *Microgaster*, and *ruficollis* an *Apanteles*. Consequently, *Xanthomicrogaster* becomes a synonym of Latreille's genus, *Microgaster*.

ICHNEUMONIDAE.

Mesostenus basimacula, Cam.

Mesostenus basimacula, Cameron, Rec. Albany Mus., i, 1905, p. 249.

Mesostenus mimeticus, Cameron, t.c., p. 250 (syn. nov.).

ANGLO-EGYPTIAN SUDAN : Kodroko, 10 ♀♀, 4 ♂♂, 10.iv.1913 (H. H. King).

Host. The above series was bred from cocoons of the Lasiocampid moth, *Anadiasa undata*, Klug, a species that is limited, I am informed, to the North East of Africa. I have also a series of this parasite bred from cocoons of the Bombycid, *Trilocho kolga*, Druce, from West Africa. Cameron originally described his species from South Africa.

Mesostenus basimacula was described from a single male, and *M. mimeticus* from a single female, and that the differences between these two are merely sexual is clearly shown by the bred series from the Sudan. *M. mimeticus* differed, according to Cameron, from *M. o'neili*, Cam. (Rec. Albany Mus., i, 1904, p. 143) on account of its mesonotum being "closely strongly transversely striated," but in the bred series before me it is apparent that this striation is extremely variable and of no specific value. *M. o'neili* is distinct, however, on account of its decidedly longer ovipositor.

It would seem from this series that *basimacula* is extremely variable in colour : particularly is this noticeable in the hind tibia, the basal fourth of which varies from altogether darkened to entirely white.

Osprhynchotus kingi, sp. n.

♀. Red ; flagellar joints about nos. 8-12, hind tibiae in basal two-thirds, hind tarsi (except basal half of the basal joint), the four apical tergites, yellow ; abdominal segments nos. 2-4, apical third of the hind tibiae, decidedly blackish to black ; ovipositor sheaths black ; wings completely and evenly violaceous as in *O. capensis*, Spin.

♂. Agrees with the above description of the female except that the apical abdominal segments are black with yellow setae.

Length, 20–25 mm.

ANGLO-EGYPTIAN SUDAN : Erkowit, Red Sea Province : 1 ♀, 10.vi.1917 (*H. H. King*—*type*) ; 1 ♀, 24.v.1917, 1 ♂, 4.v.1918 (*D. King*) ; 1 ♀, 11.v.1918 (*G. Halloran*) ; 1 ♀, 1.iv.1914 (*W. P. Lowe*).

Type deposited in the British Museum.

Host unknown.

Osprhynchotus kingi is easily separable from other species in the genus on account of the red coloration of its legs and petiole. *O. pulcherrimus*, Kirby, however, is very similar in general colour, but in this latter species at least the two basal abdominal segments are red, while the wings are not evenly violaceous throughout. *O. macro-rhynchus*, Ghigi, is distinct on account of the length of its rostrum, the rostrum and face of *O. kingi* closely resembling those of *O. capensis*, Spin.

MOSQUITO NOTES.—IX.

By F. W. EDWARDS.

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I. THE GENERA AND SUBGENERA OF ANOPHELINI.

In his catalogue of the ANOPHELINI (1924) Christophers admitted only one genus of the tribe, which he divided into five subgenera: *Anopheles* (s. str.), *Nyssorhynchus*, *Myzomyia*, *Bironella* and *Chagasia*. The position of the first three as subgenera of *Anopheles* is now universally accepted, but the arguments in favour of recognising the other two as distinct genera are worth consideration.

In regard to *Chagasia*, Root (Amer. Journ. Hyg. vii, p. 470, 1927) has pointed out that all the three known species differ from other ANOPHELINI in a number of important points, of which the most striking, perhaps, are the definitely trilobed scutellum, the form of the male palpi and front tarsi (with two well-developed claws), the structure of the hypopygium, and the peculiar spiracular plate of the larva. Other differences to which I have called attention (Bull. Ent. Res., vi, p. 124, 1926) are the form of the head and neck, and the arrangement of the hairs on the female antenna. Further distinctions are the presence (in both sexes) of hairs on the posterior pronotal lobes, and of long hairs in the middle of the sternopleura. In view of all these points, *Chagasia* appears to be amply distinct generically from *Anopheles*.

The case of *Bironella* is not quite so clear. The type species, *B. gracilis*, undoubtedly has most of the characters of *Anopheles*, s. str., its most striking differences being the extremely short radial fork and the long basal arm of the male coxite. Neither of these features is possessed by the recently described *A. (B.) travestitus*, Brug., which, on the other hand, is quite as peculiar in having the palpi very short in both sexes; a fact which, if this species is retained in *Anopheles*, will make it necessary to deal with a very inconvenient exception to the rule that the palpi of female *Anopheles* are long. Partly for this reason, I believe it will be desirable to make the most of the differences which exist, and to recognise *Bironella* as a genus distinct from *Anopheles*.

The characters common to the two species of *Bironella*, and distinguishing both from any *Anopheles*, are the following: (1) The front tarsus of the ♂ has the fifth segment shorter instead of longer than the fourth, without any bristly swelling at the base beneath, the single claw being devoid of teeth. (2) Wings with the stem of the lower fork wavy, and with *Cu* 1 rather conspicuously concave above at a short distance beyond *m-cu*. (3) Larva lgills very long and slender. (4) Hair between apical spines of antenna thick and plumose, not branched from base.*

* Since writing the above notes I have read a paper by Drs. H. de Rook & R. Soesilo in which these authors show that *Stethomyia aitheni* var. *papuae*, Swell., is a distinct species and belongs to the genus *Bironella*. They note as larval characters of *Bironella* the presence of a "fourth shoulder-hair" and of two pairs of palmate hairs on the thorax. *B. papuae* evidently falls in the subgenus *Bironella* as defined above, differing from *B. gracilis*, Theo. (= *bironelli*, Chr.) chiefly in the incomplete upper fork of the wing.

The differences between the two species are so striking that they may well be placed in separate subgenera, defined as follows :

Subgenus *Bironella*, s. str. (type, *B. gracilis*, Theo.). Antennae of ♂ plumose as usual. Palpi of ♂ almost as long as proboscis, but not conspicuously clubbed ; of ♀ not much shorter. Hypopygium with a long stout arm from base of coxite. Wings with radial fork very short, at most one-third as long as its stem. Scales of veins scanty, *An* almost or quite bare.

Subgenus **Brugella**, nov. (type, *B. travestitus*, Brug). Antennae alike in the two sexes, those of ♂ without distinct plumes. Palpi alike in the two sexes, and less than a quarter as long as the proboscis. Hypopygium without basal arm, but with four spines placed close together at base of coxite. Wings with radial fork only slightly shorter than its stem, all veins scaly, as in *Anopheles*.

In the genus *Anopheles*, I believe *Stethomyia* should be recognised as a fourth subgenus. Apart from the ornamentation of the thorax, which in the type species (*A. nimbus*, Theo.) is peculiar and distinctive, there are very marked peculiarities in the larva, of which the British Museum possesses specimens collected in Trinidad by Dr. J. R. Dickson. This larva has the anterior median clypeal hairs wide apart, as in the subgenus *Myzomyia* ; the long pleural hairs have short, thorn-like branches on one side only ; there are no float-hairs ; and the spiracular plate is quite peculiar in structure, with long finger-like processes from the lateral lobes and prominent spiracles. In the male hypopygium, the coxite bears one internal bristle near the middle, and only one spine, this being as long as the coxite itself and very strong, but not set on a tubercle as in the subgenus *Anopheles*. The anal segment is better developed than in other *Anopheles*, with quite strongly chitinised plates. The phallosome and claspette are unlike those of any other species.

These peculiarities of *A. nimbus* are not shared by *A. aitkeni* and other oriental species which have been referred to *Stethomyia* ; these species must remain in the subgenus *Anopheles*.

II. NEW SPECIES AND VARIETIES OF ANOPHELES.

Anopheles nimbus, Theobald.

I have recently examined the hypopygia of two males of this species, one taken by Mr. L. Wedekind on the Guanoco River, Venezuela, December, 1929, and forwarded by Mr. F. W. Ulrich ; the other taken by Mr. W. H. W. Komp at Almirante, Panama, February 1928, and kindly lent by him for study. These two specimens show such marked differences that they almost certainly represent distinct varieties, if not species. The Venezuelan specimen agrees with Theobald's rather rough figure of his type from Brazil ; the Panama specimen agrees rather closely with the figure given by Bonne-Wepster & Bonne of a specimen from Surinam, and is distinguished below as a new variety. No external difference is apparent.

A. nimbus, Theo., typical form. Strong spine of coxite well beyond middle, at level of internal bristle. Phallosome and claspette structures as in accompanying figure.

A. nimbus var. **komp**i, nov. Strong spine of coxite near base, far before internal bristle. Phallosome and claspette quite different from the above, practically as figured by Bonne-Wepster & Bonne (Mosquitoes of Surinam).

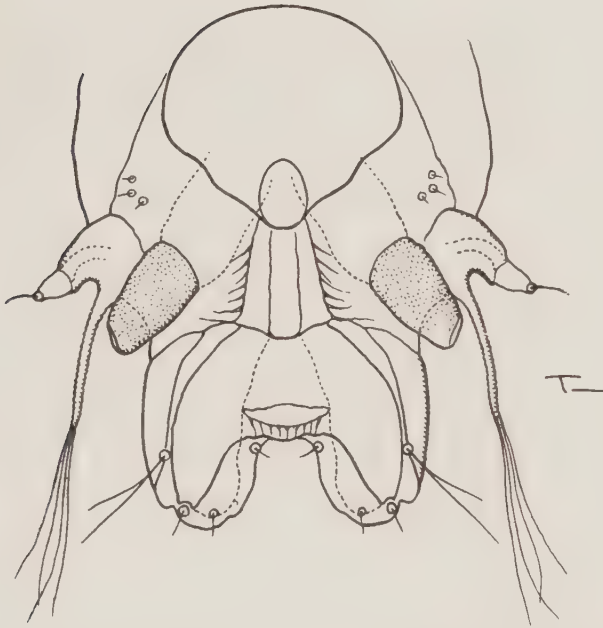


Fig. 1. *Anopheles nimbus*, Theo.: spiracular apparatus of larva from Trinidad.

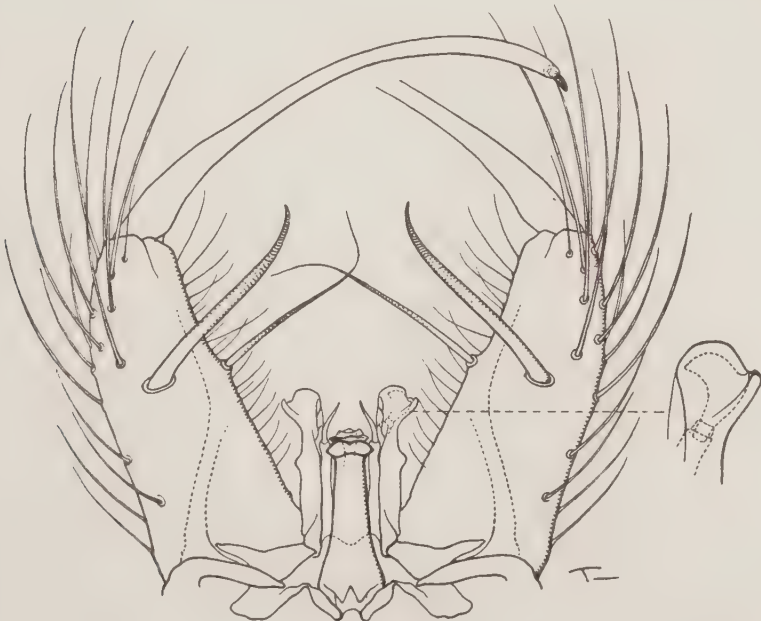


Fig. 2. *Anopheles nimbus*, Theo., type form: hypopygium of male from Venezuela.

Anopheles stigmaticus, Skuse.

In my synopsis of the Australasian mosquitos (Bull. Ent. Res., xiv, p. 352, 1924) I included *A. corethroides*, Theo., as a synonym of *A. stigmaticus*, Skuse. This, however, proves to have been an error. A pair of specimens recently received from Dr. I. M. Mackerras, collected in National Park, N.S.W., and compared with Skuse's type, show distinct differences from Theobald's specimens. In *A. corethroides* the hind femur, though pale yellowish on nearly the basal three-fourths, has a dark dorsal line extending nearly to the base; the wing-scales are uniformly dark, and the wing-membrane uniformly clear; the upper fork-cell is slightly longer than its stem in the ♂, distinctly so in the ♀. In *A. stigmaticus* the hind femur is pale yellow on rather more than the basal three-fourths, without a dark dorsal line; the wing-scales (except those on costa and fringe) are slightly paler on the apical half of the wing, and there is a slight grey cloud on the membrane towards costa in middle; the upper fork-cell is distinctly shorter than its stem in the ♂, slightly so in the ♀. There is no obvious difference in the hypopygium between the two forms; both have a single strong basal spine on the coxite, which is borne on a rather long process, this process perhaps relatively longer in *A. stigmaticus*; there is a rather strong subapical spine on the coxite, and the phallosome has about eight pairs of slender leaflets, two or three of which are very long.

The differences indicated are comparable with those seen in the varieties of *A. lindsayi*, and show that *A. corethroides* should rank as a variety of *A. stigmaticus* rather than as a synonym.

Anopheles walravensi, sp. n.

♀. *Head* with the usual dense upright scales, white in middle, black at sides; frontal tuft long and snow-white. Antennae with scape brownish, flagellum darker; first few flagellar segments with a few white scales. Palpi of moderate length, equalling proboscis; scales appressed except at extreme base; three white rings, first very narrow, at tip of first segment, second not much broader, embracing tip of second segment and base of third; third ring rather broad, including whole of fourth segment and tip of third. Last two palpal segments together slightly shorter than second, fourth about half as long as third. Proboscis moderate, black; labella brownish. Clypeus bare.

Thorax as seen from above appearing whitish-grey owing to hoary bloom, with a faintly indicated dark median line, sides of mesonotum rather narrowly dark towards the front; seen from in front the base of the scutellum and the small bare space in front of it appear blackish, and there is a small blackish spot immediately in front of the scutellum on each side; pleurae brownish, without definite markings. Mesonotum with numerous small whitish scales spread over most of its surface, leaving only small bare areas on shoulders, in front of scutellum, and towards sides on posterior half, but with numerous scales near actual margin in front of wing-base; the scales are moderately broad, about 4-5 times as long as their greatest breadth; many scales present on margin of scutellum. All mesonotal bristles dark. Prothoracic lobes with dark bristles, no scales. One very small pale spiracular hair; one dark pro-pleural bristle.

Abdomen dark, with pale hairs, but devoid of scales even on cerci.

Legs black; front legs with tips of tibia and of the first three tarsal segments narrowly white, these markings scarcely perceptible on middle and hind legs.

Wings with the outstanding scales linear and rather long. Costa mainly black; first spot (just before level of base of cubital fork) very small and present mainly or solely on lower edge of vein; second spot (just before base of radial fork) also small, but reaching front margin; third somewhat broader; all these spots, like the other pale scales of the wing, pure white. First vein broadly white at base

and with a broad white area below first costal spot; a small white dot mid-way between second and third costal spots, which extend evenly on to the first vein. Third vein white, with small black spots near base and tip. Sixth vein with three dark spots. A distinct pale fringe-spot opposite tip of each vein. Halteres with dark knob. Base of upper (radial) fork much proximal to that of lower (median). Wing-length 3.7 mm.

♂. Resembles ♀. Club of palpi mainly whitish, with a narrow black band in middle. Hypopygium with numerous small scales on coxites; its structure much as in *A. funestus*.

BELGIAN CONGO: Elisabethville (*Dr. Walravens*); cotypes, 2 ♂♂, 2 ♀♀ presented to the British Museum by the collector. Larvae were obtained in company with those of *C. duttoni* in clear water on the borders of the Luano River, 10 km. from Elisabethville; adults reared ix.1929.



Fig. 3. Wings of new African *Anopheles*: (a) *A. walravensi*; (b) *A. garnhami*; (c) *A. multicinctus*.

This species differs from *A. funestus* and *A. transvaalensis* in the ringed front tarsi and the much more distinct scales on the thorax; from *A. marshalli* and related species in the dark hind tarsi and narrow middle ring of the female palpi; from *A. distinctus* (which is perhaps its nearest relative) in having no yellow scales on the head and a dark ring on the last segment of the female palpi; the wing-markings are not quite the same in any of the species mentioned.

***Anopheles multicinctus*, sp. n.**

Resembles and is evidently nearly allied to *A. natalensis*, Hill & Haydon (*aureo-squamiger*, Theo.), differing as follows:—

Size noticeably smaller (wing-length 3.3–3.5 mm. as against 3.8–4.5 mm.). White rings on femora, tibiae and first tarsal segments somewhat more conspicuous. Hind tibia with about six narrow but complete white rings (in *A. natalensis* these are

often reduced to spots on the dorsal surface of the tibia). First hind tarsal segment with the six white rings rather broader and more evenly spaced. Second hind tarsal segment almost or quite half white (in *A. natalensis* it is at most one-fourth or one-fifth white). Fourth hind tarsal segment (as well as third) with a black ring at base. Wings with a less speckled appearance; a long pale yellowish area in middle of third vein, and another in middle of fifth vein, extending some distance along lower branch of fork. Hypopygium as in *A. natalensis*; coxite with four spines transversely placed at base (the middle two close together and not quite in line with the outer two), beyond these a long thickened hair; phallosome without leaflets.

KENYA COLONY: Taveta, Simba, ii-iii and viii.1929, 3 ♂♂, 4 ♀♀, including types; Longden, 19.iii.1929, 1 ♀ (*C. B. Symes*).

Concerning this new form Mr. Symes writes: "It occurs occasionally with *natalensis* in two districts only so far—Taveta and the Trans-Nzoia. In both places the breeding grounds of *natalensis* are in cool stream-water, clean though sometimes cloudy, with good overhanging shade (high and low) and usually between high stream banks. I have no particulars at all of the habitat of the (?) variety except these, which may not apply, of course. I managed to obtain two or three larval skins, however, and as far as I can see they appear to be identical with *natalensis*. But I am waiting for more."

Although provisionally regarded as a distinct species (no intermediate conditions in the markings of the hind legs having been observed), it is possible that this may be merely a form of *A. natalensis*. It cannot, however, be a purely geographical race, because, as noted by Mr. Symes, *A. natalensis* occurs in association with it. Kenya specimens of *A. natalensis* submitted by Mr. Symes are almost typical, differing only from those from Natal and the Transvaal in having the female palpi more broadly white-tipped, nearly half instead of about a quarter of the last palpal segment being white.

Anopheles garnhami, sp. n.

♀. *Head* with the usual dense upright scales, pale yellowish in middle, black at sides; frontal tuft long and pure white. Antennae with scape light brownish, flagellum dark; first few flagellar segments with white scales beneath. Palpi of moderate length, black, scales on first segment shaggy; a very narrow white ring at tip of first segment, a somewhat broader one embracing tip of second and base of third, tip of third and whole of fourth white; third and fourth segments together about equalling third in length, fourth short, scarcely more than one-third as long as third. Proboscis black, labella paler. Clypeus black, bare.

Thorax as seen from above greyish in middle (for about one-third of its width), sides of mesonotum very broadly dark brown, but extreme margins again narrowly grey; a small dark brown area immediately in front of scutellum in middle. Median greyish area of mesonotum densely covered with narrow scales (about 6-8 times as long as broad), mostly creamy-white in colour, but often with a stronger yellow tinge towards the sides of the scaly area, especially in front, those on front margin as usual longer and white. Dark brown lateral areas devoid of scales. Pleurae rather irregularly mottled (markings varying with incidence of light); a white area across lower edge of mesepimeron. Mesonotal bristles mainly dark, but some in front of roots of wings are yellowish. One propleural bristle; about 4-10 rather long, yellow spiracular hairs.

Abdomen brownish above, lateral and posterior margins of tergites dark brown; sternites with large and rather conspicuous whitish-grey basal lateral patches. No scales; hairs pale.

Legs blackish; coxae and trochanters pale; tips of femora and tibiae and of first two or three tarsal segments of all legs very narrowly creamy-white.

Wings with the outstanding scales narrowly ligulate. Costa mainly black, with three or four yellowish spots; first very small (sometimes scarcely distinguishable), placed just before base of cubital fork; second larger and always distinct, above stem of radial fork; third small (often absent), above middle of radial fork; fourth small, close to tip. First vein pale at base, and with three pale yellowish spots corresponding with those on costa, otherwise black. Radial fork mainly black. Third vein pale except narrowly at base and tip. No dark area on fifth vein at base of fork. Sixth vein with three dark areas, basal one short (sometimes absent). Small fringe-spots present opposite tips of all veins except sixth. Base of radial fork much proximal to that of the median. Knob of halteres black. Wing-length 5-6 mm.

♂. Resembles ♀ in colour and scaling of thorax, but pale articulations of tarsi often scarcely perceptible. Hypopygium with dark scales on coxites; structure much as in other species of the group; club long and rather narrow; claspette with long apical hair, but apparently without accessory hair; innermost of the four spines of the coxite stout on basal half, very slender and curved on apical half.

KENYA COLONY: Kericho, 6,000 ft., 15-27.i.1929, 2♂♂, 3 ♀♀, including types (*C. B. Symes*); Saiwa, 15.ii.1929, 1 ♀ (*C. B. Symes*); Londiani, 7,500 ft., 1 ♀ (*Dr. P. C. Garnham*); Uasin Gishu, 6,000 ft., 31.viii.1929, 11 ♀♀, in native huts on farm of Mr. C. W. Roberts; also 3 ♂♂, 3 ♀♀ unlabelled as to locality, with date xi.1926 (*C. B. Symes*). BELGIAN CONGO: Karambo, 6,000 ft., Ruanda, ii.1928, 1 ♀ (*Dr. J. Schwetzel*).

A. garnhami most nearly resembles and is perhaps only a variety of *A. transvaalensis*, Carter; both are subject to some variation, but the new species differs from *A. transvaalensis* in having the middle pale ring of the female palpi narrower; second palpal segment relatively somewhat longer; scales of mesonotum somewhat broader and denser, with yellowish tinge instead of being white; pale costal spots yellowish instead of white and usually less developed; no basal pale interruptions on costa (these being usually present in *A. transvaalensis*); and no dark spot at base of cubital fork.

The specimens from Uasin Gishu are somewhat larger than those from Kericho (wing-length 5.5-6 mm.) and have the wings somewhat darker, the third costal spot being absent or represented by a small dot; the spiracular hairs are also on the average more numerous. These specimens were at first thought to represent a distinct species, but there appear to be no differences other than those named. The wings of these dark specimens recall *A. christyi*.

The new species is named, at the request of Mr. Symes, after Dr. P. C. Garnham, who was the discoverer of *Anopheles symesi*, Edw., and who also collected one of the specimens of *A. garnhami*.

III. *Culex philipi*, EDW. AND *C. trifidus*, EDW.: SOME CORRECTIONS.

In a recent number of this Bulletin (xx, 1929, pp. 326-327) I described two new species of African *Culex*, *C. schwetzi* and *C. philipi*. The former was stated to be peculiar in having the antennae of the female sub-plumose, but females labelled by the collector as taken in association with the males of *C. philipi* had normal antennae with few hairs in the verticils. Further material received from Mr. Philip, however, included one or two females with sub-plumose antennae, very similar to *C. schwetzi*, (which is evidently closely related, though no doubt specifically distinct, by the structure of the male hypopygium). I have no doubt that these are the females of *C. philipi*, and that those previously associated with the ♂ of *C. philipi* were wrongly determined and belonged to some other species, probably *C. decens* or *C. perfidiosus*.

Large collections from Uganda recently received from Mr. G. H. E. Hopkins include good series of both sexes of *C. guiarli*, Bl., and *C. ingrami*, Edw., reared

from larvae. The females of both these species have sub-plumose antennae resembling those of *C. schweizeri* and *C. philipi*; the four species are evidently all nearly related and form a natural group. All of them, it may be noted, show a tendency to the duplication of the lower mesepimeral bristles.

In this Bulletin (vi, p. 108, 1926) I described a new species of *Culex* from the Sunda Is. under the name *C. trifidus*. Unfortunately this name had been used previously by Dyar for an American species, and I therefore propose the new name *C. tricuspis* for the Australasian form.

IV. A NEW AFRICAN *Culex* OF THE *pipiens* GROUP.

The *pipiens* group of *Culex* is represented in East Africa by eleven described species, some of which are rather difficult to distinguish. The new species described below is in some respects—notably the ornamentation of the thorax—the most distinct, although possessing all the characters of the group.

Culex hancocki, sp. n.

Head with the scales of the median area (both upright and decumbent) yellowish; some dark brown scales towards sides. Proboscis and palpi black; palpi in ♂ longer than proboscis by about the length of the last segment, last two segments not



Fig. 4. *Culex hancocki*, sp. n.: hypopygium of male.

very hairy, and without any obvious white line beneath. *Thorax* in ♀ with the mesonotum strikingly ornamented with stripes of yellowish scales on a dark brown ground: a median stripe extending from front margin to middle of mesonotum; a pair of stripes extending from middle back to scutellum, broadest in front; lateral margins rather broadly covered with yellowish scales on anterior half, with white scales on posterior half. In the ♂ these markings are more suffused but still distinguishable. Scales of scutellum pale. Pleurae with the usual small patches of white scales, but no postspiracular scales. *Abdomen* black above, with white basal bands on tergites, these narrowed and probably sometimes interrupted in middle in ♀. Sternites with distinct black apical bands, broadened in middle. Hypopygium of ♂ much resembling that of *C. andersoni*, Edw., but differing in detail, especially in the presence of rather numerous long hairs at and towards tip of coxite, and in the narrower leaf. *Legs* dark; front and middle femora pale behind and with a more or less distinct narrow white line running the whole length in front; hind femora whitish except on apical sixth, and with a dark dorsal line extending nearly

to base; hind tibia with a conspicuous whitish apical spot, somewhat longer than tibial diameter; tarsi dark. *Wings* with dark scales, those in the outstanding series dense and linear. Radial fork almost as long as in *C. pipiens*, almost four times as long as its stem. Wing-length about 4 mm.

UGANDA: Bulambuli, Mt. Elgon, 9,000 ft., viii.1929 (*G. L. R. Hancock*); type ♂, paratypes 2 ♂♂, 2 ♀♀, reared from larvae found in bamboos.

According to Mr. G. H. E. Hopkins, who presented the above five specimens to the British Museum, the larvae are very distinctive, having more resemblance to *C. nebulosus* than to any other *Culex*. Some were found in open cut bamboos, others in bamboos which had been bored by the larva of a moth. At a somewhat lower level on Mt. Elgon typical *C. andersoni* was found breeding in rock-pools, sometimes in company with a variety of *C. vansomereni*.

V. ON *Aedes wellmani* AND RELATED AFRICAN SPECIES.

Aedes (Finlaya) wellmani, Theo., is a species which has seldom been collected, only eight specimens, from seven different localities, having been received at the British Museum and determined as this species up to the end of 1929. Recently a good series of a species of this group has been received from Dr. W. A. Lamborn, and a study of this series together with the material previously available has shown that there are at least four closely related forms of this group occurring in Africa, apart from the South African *A. barnardi*, Edw. Some of these forms may be purely geographical races of *A. wellmani*, but this is certainly not the case with all, and they are therefore all regarded provisionally as distinct species. In the descriptions below only the differential characters are mentioned; all agree in having no metallic scales on the body; palpi of ♀ about a fifth as long as proboscis; abdominal sternites with broad apical black bands; first and second segments of middle and hind tarsi with white basal rings, those on the second segment broader.

Aedes (Finlaya) wellmani, Theo.

♀. Decumbent scales of vertex almost all broad and flat, only a few narrow ones on nape; scales mostly creamy-white, but a pair of patches of black scales above. Mesonotum with the anterior half extensively clothed with creamy-white scales, a median pair of black stripes almost reaching front margin, but not quite. Median lobe of scutellum clothed mainly with flat dark scales. Abdomen without complete dorsal bands; tergites 6 and 7 with small white median sub-basal spots in addition to the white lateral patches. Legs without purple gloss (perhaps owing to fading). Front tibia with a whitish line behind extending from base almost to tip. Front tarsus with narrow white rings at the bases of the first two segments. Middle femur (as seen from behind) with the basal half white, apical half black. Hind tarsus with the last three segments all dark. Wing-scales all dark.

♂ unknown.

ANGOLA: Bihé (*Dr. C. Wellman*).

Aedes (Finlaya) embuensis, sp. n.

♀. Decumbent scales of vertex all creamy-white, numerous narrow ones in a median stripe. Pale scales of mesonotum with a strong yellowish tint (middle of mesonotum rubbed in type, but some yellowish scales remaining on front margin; scutellum also denuded). Narrow but complete sub-basal white bands on each of tergites 5-7. Front legs as in *A. wellmani*. Middle femur white behind on basal two-thirds (hind legs missing in type). Wings with a patch of creamy-white scales at base of costa.

KENYA: Embu, 20.xii.1913, 1 ♀ (*G. St. J. Orde-Browne*).

***Aëdes (Finlaya) ingrami*, sp. n.**

♀. Head and thorax as in *A. wellmani*, except that the pair of median black stripes on the mesonotum do not reach so far forwards. Abdomen as in *A. wellmani*. Front tibia all black. Front tarsus with a few white scales at base of first segment, second segment entirely black. Middle femur (as seen from behind) mainly black, with a small white patch below on basal half. Hind tarsus with the last three segments all dark. Wing-scales all dark.

♂ (?). Differs from ♀ in having anterior two-thirds of mesonotum clothed entirely with white scales, posterior third mainly dark; all abdominal tergites with complete basal white bands; front tibia with a white line behind; wings with white scales at base of costa. Hypopygium of the usual type of the subgenus; no scale-tufts or modified hairs.

GOLD COAST: Aburi, 6.vi.1920, type ♀ reared from larva in bamboo (*Dr. A. Ingram*); Accra, iv.1916, 1 ♂ (*Dr. J. W. S. Macfie*). NIGERIA: Lagos, 10.ix.1909, 1 ♀ caught in bush (*Dr. W. M. Graham*); Oshogbo, 13.ix.1929, 1 ♀ reared from larva in tree-hole (*Dr. H. W. Kumm*). SIERRA LEONE: Daru, 20.iv.1911, 1 ♀ (*Dr. J. C. Murphy*). NYASALAND: Mt. Mlanje, 3.xii.1912, 1 ♀ (*Dr. S. A. Neave*).

***Aëdes (Finlaya) nyasae*, sp. n.**

♀. Decumbent scales of vertex all white and mostly narrow. Mesonotum with the median pair of dark stripes reaching front margin. Median lobe of scutellum with narrow scales only, some dark and some light. Abdomen as in *A. wellmani*. Legs with a stronger purple gloss than in the other species. Front tibia all dark. Front tarsus with distinct white rings at bases of first two segments. Middle femur as seen from behind mostly white on basal half, but with the upper margin dark. Hind-tarsus with the last segment more or less completely clothed with white scales, sometimes dark on one side.

♂. Differs from ♀ in having all the mesonotal scales white, no black ones even on posterior third; abdomen with complete basal white bands on tergites. Hypopygium as in *A. ingrami*.

NYASALAND: Fort Johnston, 8.xi.1929, 9 ♂♂, 9 ♀♀, reared from eggs collected in dust from rot-hole in tree (*Dr. W. A. Lamborn*).

***Aëdes (Finlaya) barnardi*, Edw.**

This has most resemblance to *A. ingrami*, differing chiefly in the ornamentation of the thorax, the white scales being much less numerous, occurring chiefly on margins and in three longitudinal lines extending from front of mesonotum to scutellum.

CAPE PROVINCE: Oudebosch (*Dr. K. H. Barnard*).

VI. THE AFRICAN SPECIES REFERRED TO *Armigeres*.

Much uncertainty has hitherto existed as to the exact systematic position of the two African mosquitos described as *Stegomyia albomarginata*, Newst., and *Dendromyia argenteoventralis*, Theo. I referred them in 1912 to *Stegomyia*, but in my list of the mosquitos of the Ethiopian region (Rev. Zool. Afr., xv, 1927) transferred both to *Armigeres*, on account of their marked resemblance both in ornamentation and hypopygial structure to the Oriental *A. obturbans*, Walk. More recently the larvae of one of these species have been discovered by Dr. L. H. Dunn, and described and figured by Miss A. M. Evans (Ann. Trop. Med., xxii, p. 39, 1928). On account of the possession by these larvae of a distinct pecten on the siphon (absent in all known Oriental *Armigeres* larvae), Miss Evans suggests sinking *Armigeres* under *Aëdes*. It seems to me, however, that whether or not *Armigeres* is retained as a distinct

genus, the African species are subgenerically distinct from the Oriental, and as they, at least, do not seem to be clearly separable from *Aedes*, I propose to include them in a new subgenus, which may be named after the first discoverer of the larvae, and defined as below.

***Aedes*, subgenus *Dunnius*, nov.**

Ornamentation as in *Armigeres*: head and scutellum with flat scales only; general colour dark; tarsi dark; pleurae densely clothed with white scales. Structural characters also much as in *Armigeres*; palpi of ♂ slender, upturned, without hair-tufts, and almost as long as proboscis; hypopygium of ♂ with numerous spines on style, no claspettes, and crenulate, divided mesosome; claws of anterior legs of ♀ toothed; cerci of ♀ short; no lower mesepimeral bristles, and no bristles on postnotum. Differs from *Armigeres* in having the proboscis more slender, distinctly longer than front femora, and not curved backwards at tip in repose. Both front and middle claws of ♂ (in the known species) very unequal, the larger claw toothed. Dorso-central and pre-scutellar bristles sometimes absent. Larva differing from *Armigeres* in having a distinct pecten on the siphon.

Sub-genotype *A. (D.) argenteoventralis* var. *dunni*, Evans.

***Aedes (Dunnius) argenteoventralis* (Theo.) (*affinis*, Theo.).**

In its typical form this species is characterised by the broad margin of white scales on the front of the mesonotum. Apart from Theobald's types (both females from Obuasi, Ashanti) I have seen only one specimen, a male from Du River, Liberia, collected by Dr. J. Bequaert, "at flower of cauliferous tree." The hypopygium of this specimen is formed exactly as figured by Miss Evans for her variety *dunni*; I therefore conclude that if *dunni* is not a distinct species, it is a variety of *A. argenteoventralis* rather than of *A. albomarginatus*. The variety is distinguished from the type form chiefly in having few or no white scales on the front margin of the mesonotum.

A long series of the variety *dunni* has recently been presented to the British Museum by Messrs. C. B. Philip and H. W. Kumm, who found the larvae abundant in bamboos and tree-holes at Lagos and Ibadan, Nigeria, in 1929. From a study of these the following characters may be indicated as diagnostic of the species:—

Head with a very narrow margin of white scales around eyes, and with a conspicuous wedge-shaped white spot (somewhat variable in size and pointing backwards) at junction of eyes in front; sometimes a small white spot on nape. Mesonotum devoid of dorso-central and pre-scutellar bristles (rarely a single pre-scutellar bristle present on one side only), but densely covered with broadly spindle-shaped, blackish scales; the scales down the middle directed outwards, leaving a definite line of parting, those towards the sides directed more backwards. Scales of scutellum all blackish. White scales of pleurae extending upwards on to mesonotum for some distance in front of wing-roots. Upper scales of posterior pronotal lobes black, all the white scales broad and flat. White spot at tip of hind tibia usually not much longer than tibial diameter. Eighth segment of ♂ abdomen not specially hairy; coxites with a densely hairy area at base, but without spines or distinct basal lobe; styles with a close-set row of spines.

In the character of the mesonotal scales and the absence of pre-scutellar bristles, this species shows a marked approach to the genus *Heizmannia*, but yet it is so obviously closely related to the species described below, which possess pre-scutellar bristles, that this character cannot (in this group) be accorded even subgeneric importance.

***Aëdes (Dunnius) kummi*, sp. n.**

Differs from *A. (D.) argenteoventralis* as follows: Head without the wedge-shaped white spot in front, though the narrow white margin to the eyes is rather more conspicuous. Mesonotum with one pair of dorso-central bristles a little in front of middle, and with one or two pairs of pre-scutellar bristles. Mesonotal scales browner and much narrower, those near middle line not directed outwards; white patches in front of wing-base less extensive; upper scales of posterior pronotal lobes narrow and white. White spot at tip of hind tibia usually about twice as long as tibial diameter. Hypopygium of ♂ (fig. 5, *a*) with the coxite somewhat longer, style entirely different in shape.

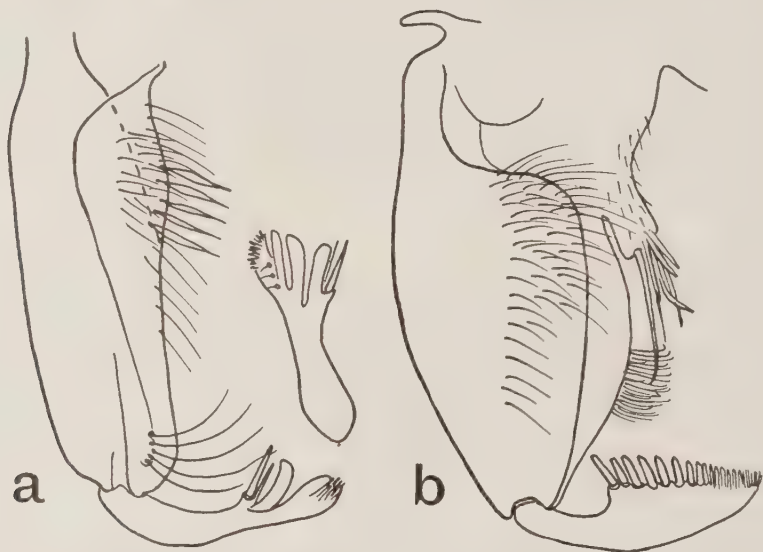


Fig. 5. Hypopygium (half) of new African *Aëdes* of subgenus *Dunnius*: (*a*) *A. (D.) kummi*; (*b*) *A. (D.) natalensis*.

NIGERIA: Ibadan, type ♂ and numerous other ♂♂ and ♀♀ reared from larvae found in tree-holes, vii-viii.1929 (*H. W. Kumm*); Lagos, reared from larvae found in cut and bored bamboos, 1929 (*C. B. Philip*). In both cases the species was associated with *A. argenteoventralis*.

***Aëdes (Dunnius) natalensis*, sp. n.**

Rather closely resembling *A. (D.) kummi*, differing chiefly in having 4-5 pairs of pre-scutellar bristles, and in the structure of the ♂ abdomen. Seventh and eighth segments broad; eighth sternite deeply concave on posterior margin, which is densely hairy except in middle. Hypopygium (fig. 5, *b*) with the coxites very stout, with a dense patch of short hair near tip on inner side, and with a distinct basal lobe bearing two or three long bristly spines; style with a close-set row of spines, but quite different in shape from that of *A. argenteoventralis*.

NATAL: Umbilo, Durban, 4.x.1914 (*L. Bevis*). Type ♂ in British Museum; a second ♂, taken at the same locality by Mr. Bevis, 30.iii.1913, was returned to the Durban Museum.

It is interesting to note that this species is closer than the others to the Oriental *Armigeres*, both geographically and structurally.

Aëdes (Dunnus) albomarginatus (Newst.).

According to information supplied by Miss Evans, Newstead's type ♀ (from the Congo) differs from all the specimens examined of the other three species in having white scales on most of the median lobe and on the sides of the lateral lobes of the scutellum, the intervening areas having dark scales; there are also narrow whitish scales on the mesonotum in front of the scutellum. The mesonotum is much rubbed, but the remaining scales on the median area are quite narrow and curved, as in *A. (D.) kummi*.

Until more and better material is available, it is impossible to decide whether Newstead's specimen represents a distinct species, or whether it is a race of the one described here as *A. (D.) kummi*.

VII. SECONDARY MALE CHARACTERS IN THE GENUS *Hodgesia*.

The small mosquitos of the genus *Hodgesia* have the sexes very much alike; not only are the palpi very short in both sexes, but the antennae of the male are non-plumose, and constructed quite as in the female; the claws of the male are small, and the hypopygium is small and often concealed within the tip of the abdomen. Nevertheless secondary male characters are to be found in some if not all species of the genus, these characters occurring in the tarsi, and to some extent recalling the condition of some species of the related genus *Uranotaenia*. I have examined males of five species of *Hodgesia*, and describe their tarsal characters below.

Hodgesia malayi, Leic.

Leicester's type male from the Malay Peninsula and a second male from Ceylon are in the British Museum. None of the tarsal segments shows any modification, but apparently there is only a single rather large claw on each front and middle leg; the empodia are small and inconspicuous.

Hodgesia sanguinea, Theo.

There are no males among Theobald's original series (from Mpumu, Uganda), but one in the British Museum collected by Major A. D. Fraser in the type locality may be presumed to belong to this species.

Front tarsi simple, with two small and equal claws, similar to those of the female, last two segments subequal in length; empodium barely distinguishable. Middle tarsi slender; last two segments bent at right angles to third, but without specially long scales; fourth segment markedly shorter than fifth; claws small and equal. Hind tarsi with the first segment slightly shorter than tibia, second and third equal in length, fourth scarcely longer than the fifth, compressed and enlarged, with longer scales dorsally and ventrally, these scales densely packed and not roughened; fifth segment with rather long sub-erect scales dorsally; claws minute as usual.

Hodgesia cyptopus, Theo. (amended from *cyptopous*).

Theobald distinguished this Gold Coast species from *H. sanguinea* by the peculiar middle tarsi of the male. It also differs in the form of the front and hind tarsi, and in markings: the third abdominal tergite has silvery lateral spots, as large as those on the other segments, whereas in *H. sanguinea* the third tergite is entirely dark. I have seen only the type male and one female.

Front tarsi not specially modified, but fourth segment markedly shorter than fifth and with rather longer scales; claws rather larger than in *H. sanguinea*, but equal;

empodium small. Middle tarsi slender, the fifth segment about twice as long as the fourth and bent at right angles to it; fourth with a tuft of very long projecting scales; a few similar long scales on tip of third. Hind tarsi simple, slender, first segment considerably longer than tibia, second longer than third, fourth quite twice as long as fifth.

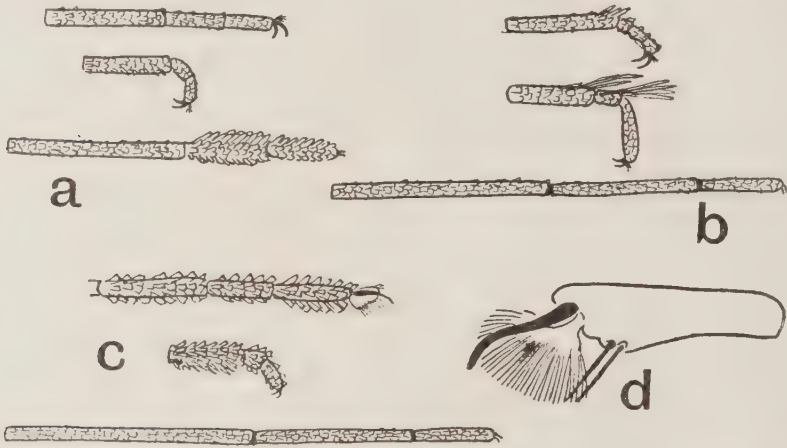


Fig. 6. Tarsal characters of male *Hodgesia*: a, last three segments of each tarsus of *H. sanguinea*, Theo., b, *H. cytopus*, Theo., and c, *H. psectropus*, sp. n.; d, last segments of front tarsus of *H. psectropus*, further enlarged.

Hodgesia nigeriae, sp. n.

Closely resembles *H. sanguinea*, and, like it, having the third abdominal tergite entirely dark; structure of hypopygium also similar. Front and middle tarsi of ♂ as in *H. sanguinea*, but hind tarsi quite slender to the tip, without long scales on last two segments; first segment slightly longer than tibia, fourth quite twice as long as fifth.

NIGERIA: Ebute Metta, near Lagos, 1929 (*C. B. Philip*), type ♂ and 1 ♀ presented to the British Museum by the collector; Badagry, 23.v.1911 (*W. S. C.*), 1 ♂ in School of Tropical Medicine, Liverpool.

This is no doubt the species of which the larval and pupal characters have been described by Wigglesworth (*Bull. Ent. Res.*, xx, p. 60, 1929) from a specimen collected at Yaba, Lagos, Nigeria, from which a female adult was reared.

Hodgesia psectropus, sp. n.

Closely resembles *H. sanguinea* in colouring and also in structure of hypopygium, but differs markedly in the tarsal characters of the male.

Front tarsi with the fourth and fifth segments subequal in length; apparently only one claw present, which is almost as long as the last tarsal segment; empodium remarkably enlarged and very hairy—a unique feature among mosquitos. Middle tarsi thicker than in the other species, last two segments more or less bent; fourth very short (scarcely as long as broad), but without unusual scales; fifth about twice as long as fourth, but still short, with two short and equal claws. Hind tarsi slender, simple; fourth segment nearly twice as long as fifth.

BELGIAN CONGO: Stanleyville (*Dr. J. Schwetz*), 6 ♂♂ (including type) reared from larvae found at edge of marsh, viii.1929; Kinshasa, x-xii.1927 (*Dr. Duren*), 3 ♂♂, 1 ♀. Presented to the British Museum by the collectors.

The pupae obtained by *Dr. Schwetz* differ somewhat in markings from the one figured by *Dr. Wigglesworth*, but appear structurally identical.

VIII. THE SUBGENERA OF *Goeldia*, *Rachionotomyia*, AND *Theobaldia*.

1. *Goeldia*.

The American genus *Goeldia* includes some species with long and some with short palpi in the male. The species with short palpi were separated by *Dyar* in his recent monograph under the name *Isostomyia*, Coq., a genus which was founded on a species of *Culex* wrongly determined as *Aedes* (*Goeldia*) *perturbans*, Williston. I consider that the name *Isostomyia* is inapplicable to *Goeldia perturbans* and should be used for the *Culex*. The name *Lynchiaria*, Brèthes, is quoted by *Dyar* as a synonym of *Isostomyia*, but again it cannot be used for the species of *Goeldia* with short male palpi. The genotype of *Lynchiaria*, *L. paranensis*, Brèthes, was described from females only; however, a male specimen which I took at San Isidro, Buenos Aires, which is no doubt this species, has the palpi almost as long as the proboscis.

The species of *Goeldia* with long palpi in the male exhibit some noteworthy structural differences, such as the absence of the squamal fringe in *G. longipes* and the short proboscis and absence of posterior pronotal bristle in the genotype, *G. fluviatilis*. However, the larvae, so far as known, are of a rather uniform type, and there seems no need to distinguish separate subgenera here. All the published generic synonyms of *Goeldia* belong to this group.

The species with short male palpi are three in number: *G. perturbans*, Will., *G. espini*, Mart., and *G. magna*, Theo. The first two are probably closely allied; both lack the posterior pronotal bristle, and the larva of *G. espini* as figured by *Dyar* is peculiar in having no posterior fringe on the siphon. The third species does not seem to be nearly related to the other two; its larva is peculiar in having the comb-teeth in one definite row attached to a chitinous bar. It would seem desirable to place these species in two separate subgenera, for which I propose the names **Isogoeldia**, subgen. n. (type *perturbans*, Will.) and **Ctenogoeldia**, subgen. n. (type *dicellaphora*, D. & K. = *magna*, Theo.).

2. *Rachionotomyia*.

This genus is closely related to *Goeldia*, but is confined to the Oriental and Australasian regions, whereas *Goeldia* is confined to America; *Goeldia* has bristles on the postnotum in all species, *Rachionotomyia* in only two species. These facts are perhaps sufficient justification for keeping the genera separate. As is the case with *Goeldia*, *Rachionotomyia* includes some species with long and some with short male palpi. For the former the names *Mimeteomyia* and *Rachisoura* are available and may be used with advantage for subgenera. The typical species of *Mimeteomyia* have the proboscis rather stout and not longer than the abdomen, but some others (*R. caldonica*, Edw., *R. rotumana*, Edw., etc.) have the proboscis long and slender, as is usual in the genus. There seems no reason why all these species should not be included in *Mimeteomyia*; in all of them the outstanding wing-scales are narrow and the postnotum bare. The type of *Rachisoura* has the male palpi about two-thirds as long as the proboscis; minute hairs present on postnotum; wing-scales all broad; and larval maxillae of peculiar form. Probably *R. latisquama*, Edw., known only from the female, belongs to this subgenus.

The species of *Rachionotomyia* with short male palpi include the majority of those known. In most the outstanding wing-scales are narrow and the postnotum quite bare; a few (e.g. *R. similis*, Leic., and *R. aenea*, Edw.) have many of the wing-scales rather broad, but some at least remain narrow. The Philippine *Wyeomyia nepenthicola*, Banks, belongs to this genus rather than to *Wyeomyia* (as shown, for example, by the form of the male antennae), but has postnotal bristles. I do not consider that this character alone will necessitate removing it from the subgenus *Rachionotomyia*, but if the contrary view be adopted, the name *Tricholeptomyia*, Dyar, is available for it.

The remaining species with short male palpi is the New Zealand *R. argyropus*, and for this I propose the new subgeneric name **Maorigoeldia**. In ornamentation *R. argyropus* is very distinctive, and it also differs from all other species of *Rachionotomyia* in possessing three or four posterior pronotal bristles instead of only one.

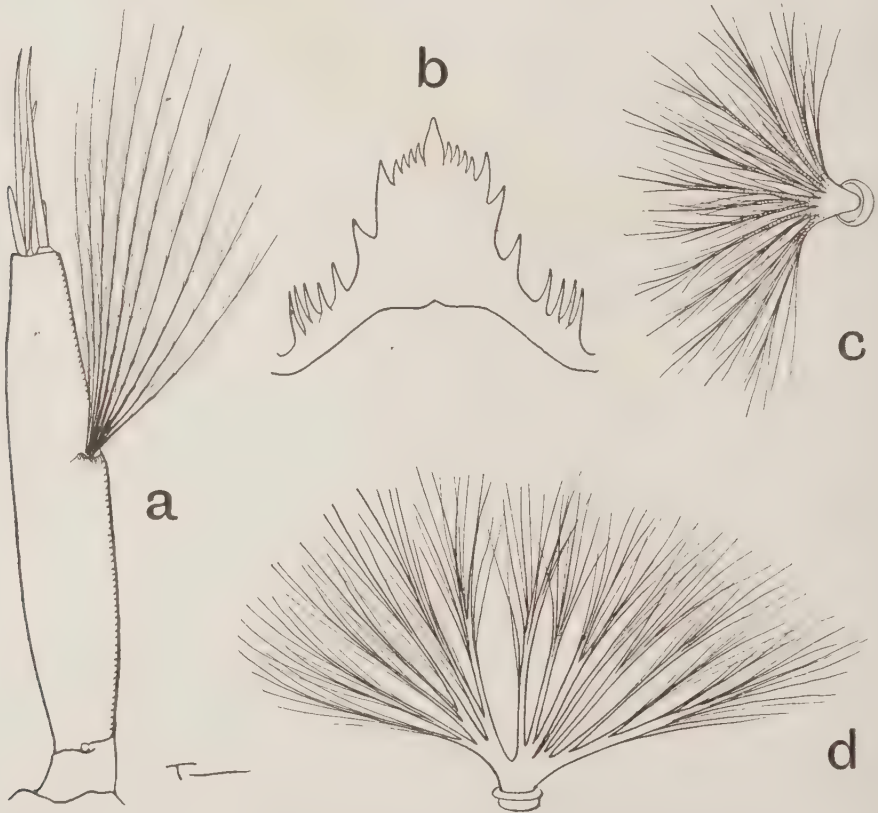


Fig. 7. Larva of *Theobaldia fraseri*, Edw. : a, antenna ; b, mentum ; c, d, small dentritic hairs from thorax and abdomen respectively.

3. *Theobaldia*.

In my revision of the Palaearctic mosquitos (1920) I recognised three subgenera of *Theobaldia* : *Theobaldia*, s. str., *Allothobaldia*, Brol., and *Culicella*, Felt. This classification has been adopted by recent writers with the addition, as a fourth subgenus, of *Climacura*, H., D. & K. This last subgenus is distinct enough in the

larval stage, but is not easily separated in the adult from *Culicella*; the most obvious distinctions, perhaps, are in the smaller number of spiracular hairs and the smaller number of hairs beneath the stem-vein. The Australian and New Zealand species of *Theobaldia* resemble the North American *Climacura melanurus* in both these respects, and should probably be referred to this subgenus, although their larvae are not yet known.

The African species which I described in 1914 as *Leptosomatomyia fraseri* belongs to the genus *Theobaldia*, but differs from all the other species of the genus in having the palpi of the male slender, bare, and less than half as long as the proboscis; there

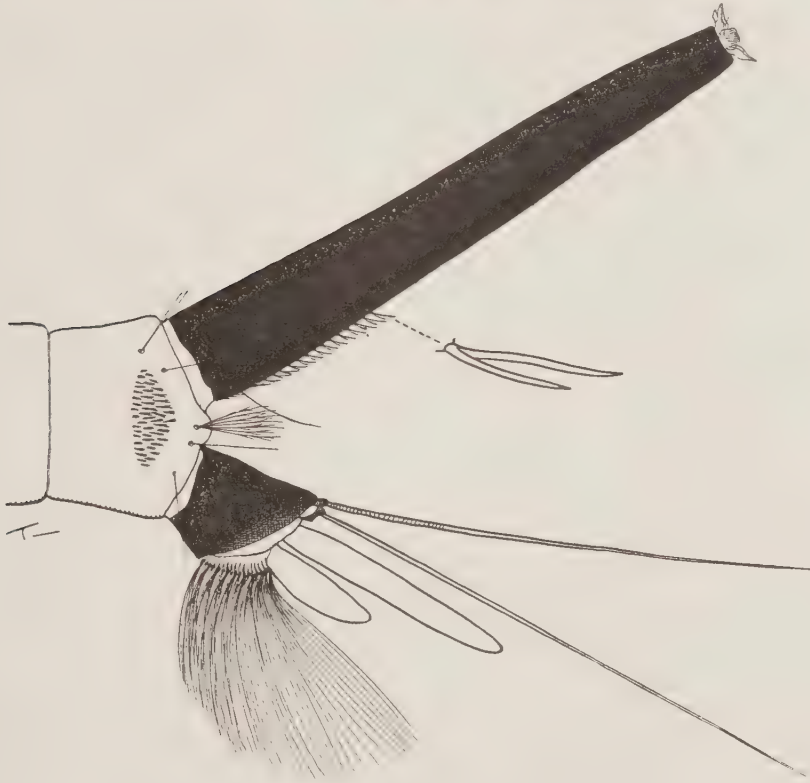


Fig. 8. Larva of *Theobaldia fraseri*, Edw., posterior end.

are only a few spiracular hairs and no hairs on the stem-vein beneath. On this account *T. fraseri* appears to require subgeneric separation, and I propose for it the new subgenus **Theomyia**.

The larvae of *T. fraseri* have recently been discovered by Dr. H. W. Kumm, who obtained them in a tree-hole at Ibadan, Nigeria. They show a number of peculiarities which support the segregation of the species in a distinct subgenus; the following brief description has been drawn up from a comparison of a series of 14 skins presented to the British Museum by Messrs. H. W. Kumm and C. B. Philip.

Head rather large and somewhat square. Frontal hairs *A*, *B* and *C* almost in line, *B* and *C* close together and moderately long, with 2-3 branches. Antenna

short, narrowly spindle-shaped, with rather large tuft at middle; all bristles apical, two rather long. Mouth-brushes rather small. Mandibles and maxillae unmodified, resembling those of *Culex* or *Orthopodomyia*. Mentum narrow, rather resembling that of *Anopheles*, with several large detached teeth at sides. *Thorax* with the chitinous bases of the hair-tufts small and inconspicuous. Prothoracic pleural group of hairs including one long single hair, two more single hairs over half the length of the first, fourth hair minute and branched. Meso- and metapleural groups each including one very long single hair, one shorter single hair, one many-branched tuft, and a fourth minute hair; between the pleural hair-groups and the dorso-lateral tuft is a small, densely dendritic hair of very unusual form. Dorsally the thorax bears towards each side two very long single hairs. *Abdomen* with rather small plumose lateral tufts on segments 1 and 2, very long single hairs on 3-6. Siphon long, but rather stout, index about 8; in colour deep black, appearing perfectly opaque even in a balsam mount; one pair of single hairs only, close to base; pecten of about 25 fine, short bristles, each of which is forked from the base. Comb of about 50 scales in a patch, scales fringed apically. Anal segment ringed by a black plate; both inner and outer dorsal hairs simple; ventral brush of about 16 rather short tufts, each tuft of many branches from a large solid base; no tufts piercing the plate; gills long.

In many respects, especially the chaetotaxy of the thorax and the first six abdominal segments, this larva bears a very close resemblance to larvae of *Orthopodomyia*, but it differs very obviously in the basal position of the siphon-tuft and the absence of chitinous plates on abdominal segments 6-8, characters which place it in the genus *Theobaldia*. It appears to be somewhat intermediate between the subgenus *Culicella* and the genus *Orthopodomyia*, with several peculiarities of its own. The form of the pecten-teeth is unique.

IX. THE SUBGENERA OF *Culex* WITH SHORT MALE PALPI.

The occurrence of species of true *Culex* with palpi equally short in both sexes is now well known, although these species still offer difficulties to the taxonomist who has to place them in subgenera. At one time I proposed to include all these species in a genus or subgenus *Micraëdes*, but a study of the hypopygia soon showed that all were not closely related, and should not be classed together; on that account I treated the possession of short palpi by the male as a character of less than subgeneric value, and distributed the species in several subgenera of *Culex* most of whose members possess long palpi. However, I am now inclined to think that it may be convenient to admit as a subgeneric character in all groups of mosquitos the possession of equally short palpi in both sexes. This will mean that in both *Culex* and *Aedes* we must recognise several subgenera with short male palpi. In both genera species occur in which the male palpi are more or less shortened, down to half the length of the proboscis, but remain distinctly longer than those of the female; such species are usually readily recognised as belonging to one or other of the main subgenera.

In the case of *Culex* five subgenera with short male palpi must be recognised: the first three purely American, the other two in the old world.

Micraëdes, Coq. (type *bisulcatus*, Coq.). Palpi about one-third as long as the proboscis; vertex with narrow scales only. Hypopygium much as in the subgenus *Microculex*.

Isostomyia, Coq. (= *Anodioparpa*, Dyar; type *conservator*, D. & K.). Palpi quite short; vertex with flat scales. Hypopygium much as in the subgenus *Melanoconion*. *C. originator*, Evans, may be placed here, although it is not very close to *C. conservator*.

Aëdinus, Lutz (= *Eubonnea*, Dyar; type *amazonensis*, Lutz). Male coxite with a long basal arm, somewhat as in the subgenus *Carrollia*.

Acaleomyia, Leic. (type *obscurus*, Leic.). Distinguished from all other subgenera of *Culex* by flat scales of scutellum and stout spine at base of male coxite.

Mochthogenes, nov. (type *malayi*, Leic., including also several Oriental and Australian species, and the African *C. inconspicuus*, Theo.). Hypopygium as in the subgenus *Neoculex*.

X. THREE NEW BORNEAN CULICINES.

Megarhinus pendleburyi, sp. n.

♀. *Head* as seen from above bluish-green, with a rather broad creamy border to the eyes. Palpi dark blue; proboscis dark green. Some whitish scales on antennal scape. *Thorax* with dark greenish scales above, scarcely metallic; a broad border of larger scales which appear pale blue in most lights, but more creamy when seen from in front, and deeper blue above wing-root. Anterior pronotal lobes mostly clothed with creamy scales, some blue scales above; posterior pronotal lobes deep azure-blue on the upper half, creamy on the lower half. Scales on remainder of pleurae creamy. *Abdomen* green above, all tergites (including first) yellowish at sides, the yellow colour somewhat more extensive on tergites 3 and 5, on 3 continued across dorsum as a narrow and ill-defined band transversely across middle of segment. Venter yellowish with median dark stripe. Lateral hairs of segments 6 and 8 orange, of 7 black. *Legs*: femora greenish, more or less yellowish beneath. Front tibia dark greenish, with some yellowish scales outwardly beyond middle, but tip itself dark. Front tarsi with first segment and base of second whitish, remainder dark blue. Middle tibiae almost entirely golden yellow, only narrowly blue at base and tip. Middle tarsi golden yellow, only the first segment broadly blue apically. Hind tibiae dark blue on about the basal half and at tip, remainder golden yellow. Hind tarsi dark blue, first segment golden yellow beneath at base, second yellowish except at tip. *Wings* normal, unmarked and slightly tinted, scales not very dense. Longitudinal portion of *r-m* scarcely twice as long as vertical. Wing-length, 6 mm.

NORTH BORNEO: Kenokok, Mt. Kinabalu, 3,300 ft., 22.iv.1929, 1 ♀ (*H. M. Pendlebury*).

The nearest relative of this new species is *M. quasiferox*, Leic., which occurs in the Malay Peninsula, Java and Sarawak. From this *M. pendleburyi* differs in leg-markings and in the conspicuously bicoloured posterior pronotal lobes.

Armigeres (s. str.) **fimbriatus**, sp. n.

♂. *Head* dark brown, with a rather broad creamy border to eyes, but no distinct pale spot on nape. Palpi normal, longer than proboscis by length of last segment. (Clypeus bare, scape with a few pale scales. *Thorax* dark, scales of mesonotum narrow and blackish; no distinct pale border, but an area of broad, flat white scales in front of wing-root, and a few narrow white scales round front margin. Anterior and posterior pronotal lobes mainly clothed with flat white scales, former with some dark scales above. No lower mesepimeral bristles. *Abdomen* dark above; tergites with lateral basal white spots which are slightly enlarged at mid-length of segment; sternites 2-6 with black apical band, 7 all black. Segments 7 and 8 with numerous very long scales projecting laterally, forming a rather irregular fringe. Hypopygium: style (clasper) broad, with a very short narrow base forming a "handle" to the comb; outer margin convex, inner straight; 25-27 teeth in a very regular row, only the first one or two shorter than the others, last tooth not lengthened. Coxite (side-piece) without definite hair-tuft; basal lobe small with four short blunt teeth, and one or two much longer, sharp-pointed spines. Halves of mesosome strongly serrate posteriorly. *Legs* dark; hind femur white on outer side to tip. Tibiae subequal,

first hind tarsal segment shorter than tibia. Front claws very unequal, larger with a long tooth; middle claws small and equal, both toothed. Wings normal, length 3.5 mm.

NORTH BORNEO: Bettatan, near Sandakan, 20.viii.1927, 1 ♂ (*C. B. Kloss* and *H. M. Pendlebury*).

This most nearly resembles *A. aureolineatus*, Leic., differing in the unicolorous mesonotum and some details of hypopygial structure, notably the absence of a hair-tuft on the coxite and the more numerous teeth on the style. The somewhat fringed appearance of the tip of the abdomen is distinctive.

***Culex* (*Neoculex*) *simplicicornis*, sp. n.**

♂. *Head* with narrow light brownish scales above; no small flat scales adjacent to eyes in middle. Antennae quite unmodified, no hair-pencil even on ninth segment. Palpi blackish, longer than proboscis almost by length of last two segments, which are upturned and hairy, terminal shorter than penultimate; few or no long hairs (and no outstanding scales) at tip of long segment. *Thorax* with brownish integument and scales; pleurae somewhat lighter than dorsum and devoid of scales. *Abdomen* blackish, tergites with complete whitish basal bands of moderate breadth. Hypopygium similar in type to species of the subgenus *Lophoceratomyia*. Style (clasper) not enlarged and without spiny crest; lobe of coxite with the usual three long stout rods, a broad leaf, and a long, flattened and somewhat twisted rod associated with the leaf; an indefinite patch (not a row) of short hairs ventrolaterally on coxite. Halves of mesosome broad and flat, with about 8-10 small tubercles towards outer margin and one spine from inner margin ventrally. *Legs* dark; first hind tarsal segment markedly longer than tibia. *Wings* dark; scales on fork-cells rather broad, almost ovate; remainder of wing scantily scaled as usual. Upper fork-cell somewhat longer than its stem. Wing-length 2.5 mm.

NORTH BORNEO: Samawang Jungle, near Sandakan, 11.vii.1927, 9 ♂♂ (*H. M. Pendlebury*).

On account of the entire absence of modified hairs or scales on the antennae, this species cannot well be placed in the subgenus *Lophoceratomyia*, to which it is evidently nearly related, the hypopygium being of similar structure, and the coloration very like *C. (Lophoceratomyia) cinctellus*, Edw. The only other oriental *Culex* with simple ♂ antennae, simple, dark-scaled ♂ palpi, dark tarsi, and basally banded abdomen is the South Indian *C. nilgircus*, Edw., which is larger and shows more affinity to the subgenus *Culiciatomyia*.

A NEW MOTH BORER OF SUGAR-CANE IN ARGENTINA (LEPIDOPTERA : PYRALIDAE).

By HAROLD E. BOX, F.E.S.

(PLATE X.)

Diatraea dyari, sp. nov.

♂. Palpus light buff. Antennal shaft honey-yellow with sparse light buff scales. Head and thorax light buff tinged with warm buff. Tergum cartridge-buff, proximal two segments warm buff; pectus cartridge-buff. Legs light buff. Venter light buff. Fore wing light buff tinged with warm buff; veins slightly infusate; a fuscous black discocellular dot; two series of fuscous dots on the veins beyond the cell, the first deeply bowed (concavity basad) from vein 7 to vein 2, sometimes forming a fuscous line continuing beyond vein 2 and bending to run obliquely into inner margin just before middle; the second series less deeply bowed, from vein 8 to vein 2; a terminal series of interneural black dots. Hind wing whitish, slightly tinged with cartridge-buff, tinged with light buff along costa; faint traces of fuscous interneural terminal dots. Underside of fore-wing light buff tinged along costa and sometimes beyond cell with warm buff; of hind wing whitish tinged with cartridge-buff, costa suffused with light buff. Expanse 30 mm.

♀. Similar, larger, colouring generally somewhat paler. Forewing with veins only very slightly infusate; fuscous discocellular dot small and indistinct, or obsolete; both series of fuscous dots on the veins beyond the cell indistinct or represented by traces, the first not continuing to the inner margin; terminal series of interneural dots indistinct or obsolete. (In many specimens the markings on the forewing are so indistinct as to leave the wing almost uniformly light buff in colour.) Hind wing uniformly whitish. Underside of forewing light buff, with veins outlined in warm buff; costal margin suffused with warm buff. Expanse 38 mm.

In both sexes the front is smooth and rounded, and without a tubercle. The hind tibia of the male is without a tuft of hair-like scales.

Holotype ♂ } *In British Museum*: Argentina, San Pedro de Jujuy (Province of Jujuy); reared from larvae in stalks of sugar-cane; adults emerged i.1929 (H. E. Box).
Allotype ♀ }

Paratypes: *In British Museum*: 2 ♂♂, 4 ♀♀, San Pedro de Jujuy (Province of Jujuy); 1 ♀, Ledesma (Province of Jujuy); 1 ♀, Campo Santo, near Salta (Province of Salta); all reared from larvae in stalks of sugar-cane, various dates of emergence, 1928-1929 (H. E. Box); 2 ♂♂, Gran Chaco, near Florenzia, x.1902 (S. R. Wagner); 1 ♀, Santa Fé, Ocampo, viii.1902 (S.R.W.); 1 ♂, 7 ♀♀, Villa Ana, Santa Fé, iv.1925 (K. J. Hayward); 2 ♂♂, 2 ♀♀, Güemes (Province of Salta), reared from larvae in stalks of sugar-cane, adults emerged xii.1928-i.1929 (H. A. Jaynes). *In Tring Museum*: 1 ♀, Corrientes, xii.1898 (Stuart); 4 ♀♀, Paraná, Entre Ríos (—); 1 ♀, La Soledad, Entre Ríos, close to boundary of Uruguay, 15.xi.1904 (Miss E. A. Britton); 1 ♀, Villa Ana, Santa Fé, ii.1927 (K. J. Hayward); 1 ♀, Salta, iv-v.1921 (—); 1 ♂, Jujuy, 28.iv.1921 (—). The following specimens presented to the *United States National Museum*, Washington, D.C., by the author: 1 ♂, San Pedro de Jujuy; 1 ♀, Calilegua, both reared from larvae in stalks of sugar-cane, adults emerged i.1929 and iv.1928, respectively (H. E. Box); 8 ♂♂, 19 ♀♀, Güemes (Province of Salta), reared from larvae in stalks of sugar-cane, adults emerged xii.1928-i.1929 (H. A. Jaynes).

This is a rather large species, which, though it bears a somewhat superficial resemblance to *D. saccharalis* (Fabricius), can be readily determined by the

characteristic genitalia (Plate x, figs. 1, 2, 3). Dedicated to the memory of the late Dr. Harrison G. Dyar, who has contributed much to our knowledge of this important genus.

Diatraea dyari is of considerable economic importance to the cane-sugar industry of the provinces of Salta and Jujuy, especially the latter, though curiously enough the species does not appear to have invaded the province of Tucumán, which adjoins Salta and is headquarters of sugar-cane cultivation in Argentina. Paratypes forthcoming from the littoral territories of Misiones, Corrientes, Entre Rios and Santa Fé, would indicate other food-plants of the larva besides sugar-cane, probably maize, an alternative food-plant of the majority of the species of *Diatraea* known to attack sugar-cane. An account of the writer's early experiences with *D. dyari* in Northern Argentina, together with some descriptive notes on the early stages, has already been published.* The general mode of life and habits of, and the type of damage done by, this species do not differ essentially from those recorded for *D. saccharalis* in the same country. In the provinces of Salta and Jujuy *D. dyari* has the following natural enemies: *Trichogramma minutum*, Riley, and a species of *Prophanurus*, which, according to Mr. A. B. Gahan, may be new to science, attacking the egg-stage; the Dexiid fly, *Paratheresia claripalpis*, Wulp (*signifera*, Townsend), which is the most important enemy of the larvae of both this species and *D. saccharalis* in Argentina, and several Braconids of the genera *Ipbobracon* and *Microdus*, which also attack the larvae. Several species of parasitic fungi have been found by Mr. H. A. Jaynes, as well as by the writer, infesting the larvae and pupae of *D. dyari*.

In conclusion the writer desires to acknowledge with sincere thanks the great help rendered in the taxonomy by his friend, Mr. W. H. T. Tams, of the British Museum (Natural History), who also very kindly made the micro-photographs of the genitalia.

* "Informe preliminar sobre el descubrimiento en la República Argentina de una especie de *Diatraea* nueva para la fauna americana."—Rev. Ind. Agric. de Tucumán, xix, no. 3-4, pp. 97-103, 2 figs., Tucumán, 1928. An English translation of this was published under the title, "Preliminary Report upon the Occurrence in Argentina of a Species of *Diatraea* new to the American Fauna," in the Reference Book of the Sugar Industry of the World, New Orleans, 1928. (Rev. App. Ent., A, xvii, 1929, p. 24.)

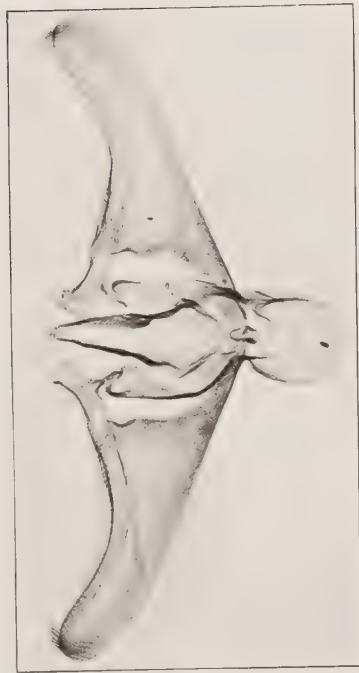


Fig. 1. Harpes, vinculum, and anellus (ventral view), ♂.

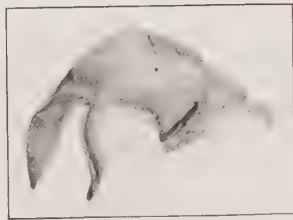


Fig. 2. Tegumen, uncus, and gnathos (lateral view), ♂.

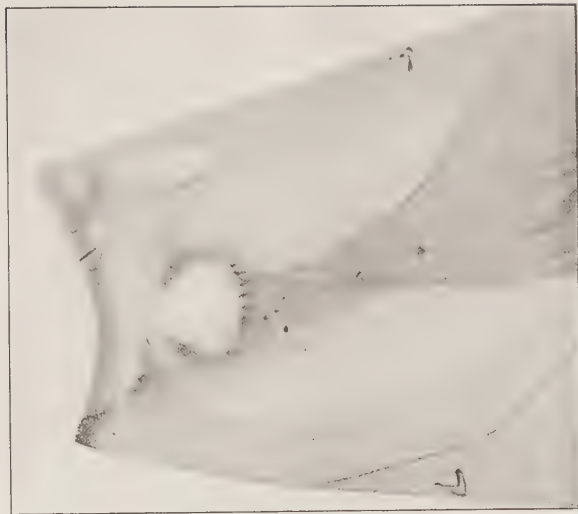


Fig. 3. Genital opening, ductus bursae, and part of the bursa copulatrix, ♀.

Genitalia of *Diatraea dyari*, sp.n.

NOTES ON PARASITES OF THE GALL-MIDGE (*JATROPHOBIA BRASILIENSIS*, RÜBS.) OF CASSAVA IN TRINIDAD.

By I. H. MYERS, M.A.

In a field of ground-provisions growing near the Imperial College of Tropical Agriculture at St. Augustine, Trinidad, it was noticed, in November 1928, that the leaves of cassava (*Manihot utilissima*, L.), which formed a large part of the crop, were attacked by a gall-forming insect. Urich (1915, p. 39) has recorded a gall-midge (*Lasioptera* sp.) as occurring in Trinidad, with one or two Hymenopterous parasites, and Bequaert (1926, p. 205) states that Felt (1921) reports having received *Cecidomyia manihot*, Felt, from Trinidad (collected by F. W. Urich).

The present study was undertaken in connection with Dr. J. G. Myers's investigation, for the Imperial Institute of Entomology, of West Indian insect pests. The writer is indebted to the Imperial College of Tropical Agriculture for laboratory facilities, to Dr. J. G. Myers for advice and criticism, and to Dr. H. F. Barnes and Dr. C. Ferrière for the determination of the midges and their parasites respectively.

A preliminary examination showed that the galls were of two main types, the most usual being a smooth, ovoid reddish gall, occurring most frequently on a variety of sweet cassava with red stems and leaf-stalks. The second type was a more irregularly-shaped, pale whitish-green gall, sometimes faintly tinged with pink, occurring on a variety of sweet cassava with pale green stem and leaf-stalk. I am assured by Dr. Stahel, of the Surinam Agricultural Experiment Station, that at the present time it is practically impossible to identify the innumerable varieties of *Manihot utilissima*. Professor Cheesman, of the Imperial College of Tropical Agriculture, endorses this statement for Trinidad, so that all that can be said is that two main types of cassava, a "white" and a "red," are planted in plots and holdings near the College, and that each type has a characteristic, though roughly similar, kind of gall. In one case, however, three types of galls were gathered from different leaves of the same plant of the white-stemmed variety and constituted a series ranging from small ovoid red-tinged galls, through yellowish galls, to larger irregular whitish-green galls.

As in the galls described and figured by Bequaert (1926, pp. 205-206, figs. 5, 6), the galls grow out from the upper surface of the leaf, having a raised, crater-like swelling on the lower leaf-surface, with a narrow opening into the gall-chamber. This opening is enlarged, presumably by the larva before pupating. The gall-chamber is a smooth-walled, narrow channel running up the centre of the gall, and in all cases examined was found to contain either a midge larva or pupa, with or without a Chalcidoid egg or larva, or a Chalcidoid pupa with or without midge remains, or pupal exuviae in the under-leaf mouth of the gall. Fused galls, with either a common mouth or separate mouths, but with fusing of adjacent wall-tissue, sometimes occurred.

Two species of Chalcidoid wasps were bred from the galls, and were also observed ovipositing in the field, namely, *Aprostocetus fidius*, Gir., which is a brown species with black-striped abdomen and prominent black ovipositor-sheath and which was obtained chiefly from red galls on the red-stemmed variety of cassava, and a dark metallic blue species of *Aprostocetus* from galls on the white-stemmed variety; but on two occasions a single specimen of *A. fidius* was reared from a pink-tipped and a white gall, respectively, from white-stemmed cassava.

The small black male of *A. fidius* was bred from collected material in the proportion of one male to three females, but was not taken in the field. No males of the blue species were bred.

Of 308 galls examined or bred out, 19 had been vacated, but whether by midge or parasite I did not determine. Of the remaining 289, 43 were from white-stemmed cassava; from 4 of these 43, the blue wasp emerged, while 17 contained the parasite, either with the midge or alone. As, however, this was not a strictly random sampling, the galls having been collected usually when seen to have been rejected or selected by the Chalcid, the rate of parasitism cannot be calculated. Of the 246 red galls, 160 contained the midge alone, *A. fidius* emerged in 31 cases, while in 55 the parasite or parasite and host, was present.

Aprostocetus fidius was first noticed (20th December) on a leaf 11 centimetres away from a gall, on which it climbed, then down to the junction of gall and leaf surface, turned round with its posterior end directed to the gall, and stayed so with ovipositor sheath held parallel to the surface of the gall. The ovipositor was not seen, and the insect flew off when I tried to catch it in a tube, but on sweeping, it was found in the net.

One captured at the same time by a field assistant was reported as alighting directly on the gall, and immediately turning backwards (with head facing leaf surface). The puncture mark, with fresh latex, was clearly visible. This observer reported several as alighting straight on a gall, others on the leaf near the gall, on to which they walked.

The flight of the insect was always more or less direct on to the leaflet with preliminary exploration in wide planes at right angles to each other, and not a hovering flight.

Another Chalcid was observed on the same morning to alight on a leaf near a gall, walk to the gall and crawl over its surface. Two galls were thus examined and rejected, the wasp in each case simply flying to another leaf and walking up to a gall, where the same procedure was repeated. After exploration of a third gall, the Chalcid took up a position longitudinal to the main axis of the gall, and facing the apex. It could be seen passing the hind legs along the ovipositor-sheath as if disengaging something. This it did three times and then remained motionless for about half a minute, at the end of which time a globule of white latex appeared as if by an explosion (one could almost hear the ping, and could certainly see it) underneath the centre of the abdomen. The insect, after an interval in which it walked over the gall and seemed to be exploring with a possibility of further oviposition, flew off to another leaflet and mounted a gall after several minutes of exploration, during which I could this time distinctly see the antennae bending forward and apparently tapping (the French word "tatonnant" most accurately describes it) the surface of the gall in a series of rapid delicate movements, which seemed to touch the gall, but may not have done so; it finally took up a position facing the leaf, and bent the abdomen over several times so that the ovipositor-sheath touched the surface. Then it ran the hind legs (apparently the third pair) over the sheath, and remained motionless while I counted about 30 seconds. At the end of that time, the abdomen was moved laterally to each side through at least 90 degrees, with apparent muscular effort, and immediately the globule of latex appeared as before, as if with the bursting of a vesicle. This I inferred was due to the retraction of the ovipositor, though I could not see the fine tube inserted, and the black sheath was always straight behind. All movements were very rapid and vigorous. It is interesting that the insect could negotiate a Euphorbiaceous plant, with the typical sticky latex, in this way.

Of twelve galls observed being actually punctured by the Chalcid, an examination 24 hours after revealed the following:—

In one case, a gall contained an inert midge larva, apparently dead, but possibly paralysed, with two clear elongated eggs, banana-shaped, with a larva plainly developing inside, against it at the head end. Another, also possibly paralysed, had one egg of the same kind under the larva. Three other larvae had no sign of

eggs, but were inert, though when I touched them the tail-end contracted. All these were a duller, slightly darker colour than healthy active larvae. The seventh contained a midge pupa, with no trace of the parasite. This gall was on a leaf with an unpunctured gall, from which a midge emerged the same day.

The eighth and ninth had in them respectively one large and one small unhealthy-looking flaccid larva, I think dead, extended so that they were thinner and longer than the normal midge larva, but with no signs of the parasite. The tenth contained one midge larva, also apparently dead, dull and cloudy in colour, and having an egg on each side of the head; the eleventh, a midge pupa, no parasite detected. The twelfth had a large deliquescent midge larva, obviously dead, and a long, pointed egg lying on the wall of the gall underneath it, and directly above the puncture in the gall. In each of the two rejected galls was found a large larva very dried up, one having an egg attached in the middle of one side.

The egg was often not seen in galls examined soon after oviposition, though in many cases examined after a longer interval, sometimes even of a day, the clear white banana-shaped egg could be seen near hatching. Very rarely two eggs were present. The egg was variously attached, often at the head-end of the host, but sometimes on the body, while sometimes it was merely lying on the wall of the gall, under the body of the host. In many cases, though no egg was observed, the larva of the midge was seen to be sluggish, relaxed, and even, if the examination was delayed, duller in colour.

Several galls with puncture marks outside were found to contain midge larvae or pupae with brown spots, which looked like puncture-marks on the skin. These spots are not found in the unattacked host, and raise the question of possible paralysation. This question cannot be decided at present. Certainly parasitised larvae were often found in the galls fresh, though inert, and duller in colour (but not always so), and no heart or peristaltic action was perceptible, the latter being pronounced in the normal larvae, the former sometimes visible. But there was nothing to indicate in the majority of these cases that the host was not dead and simply preserved in the interior of the gall. However, on certain occasions, when I touched such inert larvae, the posterior end was moved. In other cases, the midge larvae when parasitised were either in a state of juicy disintegration internally, or partly collapsed and sucked. In one case a punctured gall was found to have in it a Chalcid larva together with a dark brownish collapsed midge-larva, adhering at the head-end to the top of the gall, so that I had to pull strongly with the forceps to detach it. (I had before noticed this adherence in several cases of sluggish or of parasitised larvae.) The abdomen of the midge-larva was sucked dry, but became extended in *liquide de Faure*; the head-end was still full, retaining its yellow colour to a certain extent. The integument had numerous brown pigmented spots. The Chalcid larva on this as on other occasions was so turgid that it burst as the cover slip for a water-slide was being put over it.

There is also a likelihood that some at least of the brown spots referred to are feeding marks, as they were often found to be numerous when the host-larva or pupa had a fairly advanced parasite-larva present with it.

In several cases the larva in a punctured gall had no apparent sign of an egg, but a later second inspection showed an active parasite larva to be at work. The larva was always free, crawling energetically over the host or about the walls of the gall. In most instances the parasite-larva was found crawling on, or present in the gall with, the larva of the host, which was sometimes partly consumed or even in a state of disintegration. Several times, however, the parasite was present with a host-pupa, often brownish and soft.

A very fat, fully-fed parasite larva was several times found with no remaining traces of the host ; while in one instance a sluggish, engorged larva was present with an empty skin of a midge-larva.

The larva of the parasite pupated simply, without cocoon, in the gall-chamber, as did also that of the host. The partition mentioned by Bequaert as being spun by the pupating midge was not normally observed, but on two occasions a partition was found to have been made ; on one occasion, whether by midge or parasite is not certain. In the first case a gall was cut open, and being found to contain a midge pupa and two parasite eggs, was kept for rearing ; there was found seventeen days later, near emergence, a pupa of *A. fidius*, the larva of which had apparently spun itself a covering to the cut end of the gall. It did not, however, achieve this, as it became dessicated. This case would seem to indicate that the parasite larva forms a partition, as Bequaert records for the midge. In the second case a red gall which contained a pupa of the parasite in an upper compartment had a small midge larva in a lower one, at the mouth end of the gall ; but as the galls had been cut from leaves and enclosed in a glass tube, the larva may have wandered from its own gall, as others frequently did after disturbance by examination, and entered the occupied gall, instead of, as usual, wandering to the side of the tube.

In this second case there is no indication whether the partition enclosing the pupal chamber was made by the host larva or the parasite larva. This might depend on the stage of development of the former when first parasitised ; probably, as stated above, both parasite and host do this before pupation, as no cocoon is spun in either case.

Emergence, both of parasite and host, takes place as described by Bequaert through the artificially enlarged opening of the gall on the lower surface of the leaf, the pupal exuviae being left in the opening. The enlarged opening is a constant indication of the presence of a pupa of a midge or Chalcid.

The handsome metallic-blue Chalcid (*Aprostocetus* sp.) was observed ovipositing on a subsequent occasion, in a whitish, pink-tipped gall, on the pale-stemmed variety of cassava, and while its general behaviour was very similar to that of the above species, there were slight differences which might almost be ascribed to difference of temperament. The movements of this insect were even more vigorous and business-like, and almost every stage in the action-chain more clearly defined, than those of *A. fidius*.

The individual observed was first seen walking on a cassava leaf-lobe ; it then mounted a gall, bent its abdomen at right angles to the body-axis, with ovipositor-sheath against the gall, but no insertion took place. It then walked to another gall on the same leaflet, repeated this action, and flew off to another leaf, where a gall was selected and oviposited in. This process was repeated on other galls, and the general behaviour may be described in the following way :—

The insect in each case " feels " the gall with its antennae, then takes any position on the gall and bends the abdomen over at right angles. It strokes the sides of the abdomen with its hind-legs, then bends it over again, sometimes several times. Then the abdomen becomes straight again, while the insect remains still, save for a slight swaying on its legs, which at times becomes more marked ; the abdomen is twisted from side to side and sometimes bent a little down, until finally a spot of latex appears under the abdomen, about the middle, and the insect moves away to another part of the same gall. It lays several times in different parts of the gall, sometimes remaining from ten minutes to a quarter of an hour on one gall, puncturing numbers of times, and sometimes a gall is abandoned without laying, after several bendings of the abdomen.

The bending of the abdomen in extracting the ovipositor is not so pronounced as in *A. fidius*. The abdomen after insertion becomes gradually straightened from

the right angle or an even greater curve, then becomes recurved, and one can observe a vigorous pumping motion up and down, then a slewing from one side to the other, so that sometimes the insect turns its whole body round and then back, until, after about a minute, it seems to be pulling up the ovipositor, and the spot of latex appears.

A certain amount of rubbing of the abdomen with the hind legs takes place after laying. In the cases under observation, the insect became so absorbed that I could hold the lens quite close to it. I saw it with antennae quivering and bent over seeming to touch the gall as it went; several times it bent the abdomen down and touched the gall with the tip of the ovipositor-sheath, and then moved on. Sometimes it even partly inserted the ovipositor, withdrawing the sheath and abdomen, but almost immediately withdrew it, not inserting fully. When it did lay, the ovipositor was seen to be gradually pushed in as the abdomen was curved up, so that the abdomen was touching the gall only at the point of attachment of the ovipositor. There was much trembling of the antennae, which were bent forward, but not touching the gall, then a period of some seconds in which the insect remained perfectly still; then the abdomen was twisted to the left for some seconds, and a slow slewing and pulling was performed, till finally in about one minute the insect rose on its legs, withdrew its ovipositor and moved off to another part of the gall. Under the lens, cleaning of all legs and of the abdomen after oviposition could be seen, as well as of the antennae. Periods of resting on the leaf in between oviposition or exploration also occurred.

The wasp was captured after four galls had been oviposited in. Five days later two of them had each a Chalcid pupa, one with an unhealthy mass of midge larva, the other with no trace of midge.

The egg of the blue Chalcid is not definitely known. As in the case of *A. fidius* the larva was free, moving actively over the host, larva or pupa. The brownish puncture or feeding marks were also observed. The host was also sometimes found in a state of soft, partial decay, and occasionally the fully-fed parasite had no remains of the host present.

Pupation occurred in the gall chamber, no spun partition being observed. The under-leaf opening was found to be enlarged as in the case of *A. fidius*, and emergence took place through this.

The method of rearing was the same for both Chalcids. Galls collected were placed, if possible with the adult parasite, in glass tubes, corked, with a strip of blotting paper running down one side of the cork, on to the tube; as a certain amount of sweating took place, the tubes were wiped out every morning and the material replaced when they were being examined for fresh emergences. It was found that even though galls sometimes went mouldy in the tubes, yet the insects still hatched out; but in the case of those placed in small wooden breeding boxes, or cardboard pill-boxes, dessication of gall and larva took place over-night.

In no case was an adult parasite bred successfully through from observed oviposition or the egg-stage, but insects sometimes emerged after sixteen days of keeping in this way.

Galls found on opening to contain parasite pupae were put together again and placed in gelatine capsules, in many cases successfully producing the adult.

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RECORDS OF SARCOPHAGIDAE WITH NEW SPECIES.

By B. ROHDENDORF.

The following records are based on a collection of SARCOPHAGIDAE submitted for identification by the Imperial Institute of Entomology.

Sarcophaga melanura, Meig.

Palestine : 10 ♂♂, 2 ♀♀ from Jaffa, Jericho, Jerusalem and Haifa, 1924 (G. F. Hucklesby), 1929 (J. Tapukhi). China : Shantung, 4 ♂♂ from Tsinan and Taishan, 1926 (E. Hindle).

Sarcophaga destructor, Malloch 1929.

Cyprus : 4 ♂♂, 2 ♀♀, vii.1927 (H. M. Morris); 2 ♂♂, 1 ♂, 1 ♀ in copula, bred from tomato vii.1925, and from melon 22.vii.1925 (C. Papa Chrisostomou); 4 ♀♀, bred from figs (D. S. Wilkinson). Sudan : 4 ♂♂, 3 ♀♀, Khartoum, 28, 30.x.1926, bred from melon (Abdallah Hassan), 6.xi.1926, bred from water-melon (H. B. Johnston), 15.ii.1928, bred from melon (H. W. Bedford); 1 ♂, 2 ♀♀, Wad Medani, 4.i.1923, 11.xii.1925, bred from melon (H. W. Bedford); 1 ♂, 1 ♀, Bonga, 20.iii.1923, larvae in water-melon (H. H. King); 1 ♂, Shambat, 1.x.1928, from melon (H. W. Bedford).

This species was described by Malloch (Ann. Mag. N. H. (10) iv, 1929, p. 255, fig. 4) from the Sudan as a parasite of the desert locust (*Schistocerca gregaria*, Forsk.). The 28 ♂♂ and ♀♀ enumerated above from Cyprus and the Sudan, bred from melon and water-melon, make it possible to doubt the correctness of the biological observations of King and Bedford, who reared 4 flies of this species from *Schistocerca gregaria*.

Sarcophaga carnaria, Meig.

Palestine : 5 ♂♂, Jerusalem and Upper Galilee (G. F. Hucklesby, 1926 and J. Tapukhi, 1929).

Sarcophaga exuberans, Pand.

Palestine : 4 ♂♂, 2 ♀♀ from Jerusalem and Haifa (G. F. Hucklesby, 1926 and J. Tapukhi, 1929).

Sarcophaga albiceps, Meig.

Palestine : 1 ♀ from Jerusalem (J. Tapukhi, 1929).

***Sarcophaga sinica*, sp. n.**

♂. Frons equal to 0.19 of head. Third joint of antennae twice the length of the second. Verticals (interiores) diverging; laterals weak, diverging; frontals strong, crossed. Ocellar bristles weak and short. Facials weak, below much longer. Vibrissal ridge bare. Thorax with two strong pairs and three hair-like pairs of postsutural dorsocentral bristles. Acrostichals only present as praescutellars. Scutellum with strong subapical and basal bristles; apicals, dorsals and praebasals weak, ordinary. Laterals wanting. Middle femur without ctenidium, with row of long bristles. Middle and hind femora and tibiae fringed and rough. Hind femora curved and without lower row of bristles. Vein r_1 bare, r_4 and 5 with three short bristles at the base. Segment 3 of costa half as long again as 5. Angle of m acute. Posterior cross-vein S-shaped. Costal bristle very short. Third abdominal tergite without middle marginal bristles. Genitalia similar to those of *S. orientalis*, Parker, and *orientaloides*, Senior-White. Superior forceps with hair-tuft in middle of distal edge. Distal edge of forceps curved, without bristles. Inferior forceps prominent, hairy. Palpi genitales longer than forcipes interiores, long. Interior forceps short,

with long hairs. Thorax black, dusted with brownish grey. Dorsum with three black longitudinal stripes. Wings and alulae infumate, calypters white. Frons and face pale dull golden pollinose. Antennae, frontal stripe and palpi black. Genal hairs pale yellowish. Colour of abdomen as usual, brownish grey pollinose. Tergite 7 (=1st genital) blackish, brown to yellowish brown pollinose; at the hind margin without bristles. Tergite 8 shining black (fig. 1). Length of body, 14 mm.

China: Foochow, 1 ♂ (*C. R. Kellogg*).



Fig. 1. *Sarcophaga sinica*, sp. n.: male genitalia.



Fig. 2. *Sarcophaga sera*, sp. n.: male genitalia.

***Sarcophaga sera*, sp. n.**

♂. Frons equal to 0.20 of head. Third joint of antennae equal to 2.5 times second. Verticals (interiores) straight. Lateral verticals absent. Frontals strong, crossed. Ocellars weak. Facials weak, inferiorly much stronger. Vibrissal ridge bare. Thorax with two strong pairs and three hair-like pairs of postsutural dorso-

centrals. Acrostichals only present as praescutellars. Scutellum with strong subapical and basal, and with weak apical and dorsal bristles. Laterals absent. The sides of scutellum with short numerous dense bristles, similar to those of *Thercomyia* (MILTOGRAMMATINAE). Middle and hind femora and tibiae fringed. Middle femora without ctenidium, with row of long bristles. Hind femora with anterior row of bristles. Vein r_1 , bare, r_4 and $_5$ bristly from half-way to rm cross-vein. Angle of m acute. Segment 3 of costa 1.5 times as long as 5. Posterior cross-vein S-shaped. Costal bristle very short. Frons and face pale golden pollinose. Antennae, frontal stripe and palpi black. Genal hairs whitish posteriorly. Thorax



Fig. 3. *Sarcophaga sera*, sp. n.: internal genitalia of male.

black, yellowish to brownish grey pollinose, with three longitudinal black stripes. Legs black, femora pollinose. Wings hyaline, yellowish at the base. Abdomen black, brownish grey pollinose. Genitalia shining black, tergite 7 (=1st genital segment) yellowish pollinose posteriorly, without marginal bristles. Superior forceps short, in distal part with hair-tuft dorsally. Distal tip of forceps incised preapically. Penis, see figs 2 and 3. Length of body, 10.5 mm.

China: Foochow, 1 ♂, 1928 (C. R. Kellogg).

Sarcophaga ruficornis, Wied.

India: 1 ♂, 2 ♀♀, Gurdaspur, Punjab, 1922 (D. Nath), reared from Sphingid larva on *Quisqualis*.

Sarcophaga haemorrhoidalis, Meig.

Palestine: 4 ♂♂, 2 ♀♀, Jerusalem (G. F. Hucklesby and J. Tapukhi). China: Shantung; 1 ♂, Tsinan, 1926 (E. Hindle).

Sarcophaga ferculata, Pand.

Palestine: 1 ♂, Jaffa District, 1926 (G. F. Hucklesby).

Wohlfahrtia (s. str.) *magnifica*, Sch.

Cyprus: 1 ♂, 2 ♀♀, Nicosia (R. S. Roe), bred from larvae in dog's foot.

Sarcophila latifrons, Fall.

China: 1 ♀, Tsinan, Shantung, 1929 (E. Hindle).

Blaesoxipha (s. str.) **filipjevi aequatorialis**, subsp. n.

Very similar to *B. f. tertia*, Rohd., and *B. f. filipjevi*, Rohd. Length of body 4-6.5 mm. Second and third antennal joints on inner side and palpi red. Frons of male narrow, 0.13-0.17 of width of head; of female broad, 0.26-0.28 of head. Legs of female red-yellow. Thorax black with dense brownish (♂♂) or yellowish (♀♀) grey dust. Mesonotum with three dark brown vittae. Female without mesonotal vittae, only with three longitudinal brownish spots. Abdomen of the usual colour. Genitalia reddish. Superior forceps in basal part high. Forceps even ventrally. Palpi genitales blunt at the tip, weakly dilated.

Tanganyika Territory: Makania, 2 ♂♂, 4 ♀♀; 22.i.1929 (*A. H. Ritchie*), reared from *Schistocerca gregaria*; Mlali, 1 ♂, 18.vi.1929 (*W. V. Harris*), reared from *Anacridium moestum*.

Blaesoxipha (*Gesneriodes*) *lineata*, Fall.

China: 2 ♀♀, Tsinan, Shantung, 20.vii.1926 (*E. Hindle*).

GALL MIDGES (CECIDOMYIDAE) AS ENEMIES OF THE TINGIDAE, PSYLLIDAE, ALEYRODIDAE AND COCCIDAE.

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1. Introduction.

This is the second of a series of papers dealing with zoophagous gall midges of the world. The first, "Gall Midges as Enemies of Aphids," appeared recently (Bull. Ent. Res., xx, 1929, pp. 433-442), while the third dealing with gall midges as enemies of mites is in course of preparation.

In this paper the species of gall midges whose larvae have been reported as preying on TINGIDAE, PSYLLIDAE, ALEYRODIDAE and COCCIDAE, are dealt with in that order, the first reference mentioned being in each case that of the original description. These complete the families of Hemiptera on which CECIDOMYIDAE are known to be predacious. Practically all the information available consists of specific descriptions and very little is stated about the bionomics of the species. This is deeply to be regretted. A list of the species of Hemiptera attacked by gall midges and dealt with here is added.

I am indebted to Mr. F. Laing, of the British Museum (Nat. Hist.) for his very kind assistance with regard to Coccid nomenclature.

2. Addenda to "Gall Midges as Enemies of Aphids."

Feltiella davisi, Felt.

Felt, JI. Econ. Ent., viii, 1915, pp. 406-407; N.Y. St. Mus. Bull. no. 202, 1918, pp. 170-171.

Male and female described from midges reared in 1915 from catnip leaves infested with *Aphis gossypii*, Glov., at Lafayette, Indiana, U.S.A.

Trilobiella siphæ, Del Guercio.

Del Guercio, Note ed Osservazioni di Entomologia Agraria, Not. Prelim., Bibl. Agr. Colon., 1918, pp. 244-246; L'Agric. Col., Florence, xiii, 1919, pp. 181-183.

Larva described and noted as feeding on *Sipha maidis*, Fitch, on maize, probably in Italy.

Unknown Cecid.

F. V. Theobald (The Plant Lice of Great Britain, ii, 1927, p. 267) reports finding Cecid. larvae feeding on *Anuraphis tragopogonis*, Kalt., on *Tragopogon pratensis*.

3. Gall Midges whose Larvae attack Tingidae.

Endopsylla endogena (Kieffer).

Kieffer, Zeits. f. Hymen. u. Dipt., i, 1907, p. 129-130 (*Cecidomyia*); Genera Insectorum, fasc. 152, 1913, p. 222 (*Endopsylla*).

Male and pupa described. Kieffer bred a single male from a dead larva of *Stephanitis pyri*, F. Pupation took place inside the Tingid and the adult emerged through a circular hole in the back of the host. The insects were sent by Tavares from Portugal. This species seems to be the most specialised gall midge yet known, being the only one known to live as an internal parasite and pupate inside its host.

Two or three other species, *E. agilis*, de Meijere, *Endaphis perfidus*, Kieffer, and *Endaphis* sp. (see below and Bull. Ent. Res., xx, 1929, p. 433), are internal parasites, but leave their hosts in order to pupate.

4. Gall Midges whose Larvae attack Psyllidae.

Endopsylla agilis, de Meijere.

de Meijere, Tijds. v. Ent., i, 1907, pp. 170-174.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 222.

Bagnall & Harrison, Ent. Rec., xxxvi, 1924, p. 38.

Male, female and larva described from Holland. The larvae are endoparasites of *Psyllia foersteri*, Flor, on alder, up to four larvae being found in one *Psyllia*. Pupation takes place in the soil. It is to be noticed that this midge is endoparasitic in the winged *Psyllia* (vl. *Endaphis perfidus*, Kieffer, endoparasitic in wingless Aphids and *Endopsylla endogena* (Kieffer) in the larva of *Stephanitis pyri*). Bagnall & Harrison report it from Northumberland, England.

Lestodiplosis liviae, Rübs.

Rübsaamen, Schrif. Naturf. Gesell. Danzig, x, 1901, pp. 94-95.

Kieffer, Monographie des Cecidomyides, 1901, p. 333.

Bagnall & Harrison, Ent. Rec., xxxvi, 1924, p. 38.

Rübsaamen described both sexes of this species, which he found living in the galls of *Livia juncorum*, Latr., in West Prussia. Since the larvae of this genus are predacious, presumably the Cecidomyid lives on the *Livia*. Bagnall & Harrison recorded the larvae as inquilines in the galls of *L. juncorum* on different species of *Juncus* in Durham.

Besides these two species, Kieffer (1901) mentions a *Lestodiplosis* which lives at the expense of *Aphalara maculipennis*, F. Lw., and also a *Bremia* observed by Rübsaamen in the galls of *Psyllopsis fraxini*, L. W. Speyer (Monographien z. Pflanzenschutz, I. Der Apfelblattsauger, 1929, p. 67, fig. 6) mentions an undescribed species of CECIDOMYIDAE whose larvae suck the apple-sucker and whose eggs apparently are laid on the wing of *Psyllia mali*, Schmid.

5. Gall Midges whose Larvae attack Aleurodidae.

Cleodiplosis aleyrodica, Felt.

Felt, Proc. U.S. Nat. Mus., lxi, 1922, article 23.

Felt described the male and female of this species of which considerable numbers were reared from the whitefly, *Aleurodicus (Lecanoides) giganteus*, Quaint. & Baker, at Panama City in 1919.

Unknown species of Cecidomyidae.

Mr. G. F. Wilson, entomologist to the Royal Horticultural Society, has very kindly allowed me to note that he has found Cecidomyid larvae feeding on the nymphs of *Trialeurodes vaporariorum*, Westw., on *Eupatorium glandulosum*, 22.vi.1922, at Wisley. Felt (Jl. Econ. Ent., vii, 1914, p. 458) cites *Lestodiplosis* sp. as feeding on *Aleyrodes*.

6. Gall Midges whose Larvae attack Coccidae.

Slightly over forty species of gall midges are known or presumed to be predacious on Coccids. Dr. Imms has kindly allowed me to note here that he has reared an unidentified Cecidomyid from twigs covered with apple mussel scale. Kieffer states (1901) that Rübsaamen had observed a species of *Bremia* feeding on the larvae of

Chionaspis vaccinii, Bouché (= *salicis*, Linn.). Further, Dr. F. S. Bodenheimer has recorded from Palestine a midge whose larvae feed on the eggs of *Pseudococcus citri*, Risso. This species has been studied in connection with the artificial control of the citrus mealybug (Bodenheimer, Palestine Citrograph, i, 1928, no. 5 and 6, reprint pp. 12-14; Bodenheimer & Gutfeld, Zeits. f. ang. Ent., xv, 1929, pp. 122-130).

Megauchomyia africana, Felt.

Felt, Jl. N.Y. Ent. Soc., xxxvi, 1928, pp. 123-124.

Male and female described from midges taken by Dr. Jos. Bequaert of the Department of Tropical Medicine, Harvard University Medical School, as they were hovering over Coccids in Liberia. It may be a parasitic species.

Microperrisia pulvinariae, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, pp. 174-175.

Male and female described from specimens received from H. S. Smith of the California State Commission of Horticulture, labelled as reared from *Pulvinaria* on *Citrus* in Manila, P.I.

Coccomyza brittini, Del Guercio.

Del Guercio, Note ed Osservazioni di Entomologia Agraria, Not. Prelim., Bibl. Agr. Colon., 1918, pp. 264-271.

Larva and fully developed pupa described and noted as found as an enemy in Eriococcid galls on leaves of *Olea* in New Zealand.

Coccidomyia erii, Felt.

Felt, Jl. N.Y. Ent. Soc., xx, 1912, p. 147; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 175, 1915, p. 211.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 49.

Essig, Insects of Western North America, 1926, p. 550.

This midge was reared by P. H. Timberlake in 1911 from *Artemisia californica* infested with *Amonostherium lichtenstoides*, Ckll., collected near Carpenteria, Ventura County, California. Male and female were described by Felt (1912). Essig states that it feeds on *Amonostherium lichtenstoides* (Ckll.) in South California.

Coccidomyia pennsylvanica, Felt.

Felt, Jl. N.Y. Ent. Soc., xix, 1911, p. 45; Jl. Econ. Ent., iv, 1911, p. 475; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 175, 1915, pp. 210-211.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 49.

Male and female described by Felt (1911), received from W. S. Fisher of Highspire, Pa., and stated to have been reared from beech leaves, probably *Fagus grandifolia*, thickly infested with young *Lecanium* scales from under which Dipterous exuviae projected.

Streptodiplosis indica, Felt.

Felt, Canadian Entom., xlvi, 1916, pp. 405-406.

Male described from a single specimen labelled "on leaves infested by *Mytilaspis piperis*, Green, South India." Probably predacious upon this insect.

Dentifibula ceylanica, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, pp. 175-176; N.Y. St. Mus. Bull., no. 202, 1918, pp. 131-132.

Male described. Reared by A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, in 1914, from twigs of *Cassia alata* infested with a species of *Hemichionaspis* (syn. *Pinnaspis*).

Dentifibula cocci, Felt.

Felt, N.Y. St. Mus. Bull., no. 124, 1908, p. 389; Jl. Econ. Ent., iv, 1911, p. 475; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 131. Kieffer, Genera Insectorum, fasc. 152, 1913, p. 174.

Male described. Reared in 1897 from *Aspidiotus uvae*, Comst., taken in Illinois.

Dentifibula obtusilobae, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, p. 176; N.Y. St. Mus. Bull., no. 202, 1918, pp. 131-132.

Male and female described. Reared by A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, in 1914, from *Piper nigrum* infested with *Pinnaspis aspidistrae*, Sign., and a few specimens of *Aspidiotus lataniae*, Sign., probably the larvae were feeding on the former.

Dicrodiplosis antennata, Felt.

Felt, Jl. N.Y. Ent. Soc., xx, 1912, pp. 243-244; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 156.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 157.

Male and female described. Reared by O. H. Johannsen, Orono, Maine, in 1912, from reddish orange larvae preying on the false maple scale, *Phenacoccus acericola* (King).

Dicrodiplosis californica, Felt.

Felt, Jl. N.Y. Ent. Soc., xx, 1912, pp. 244-245; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, pp. 155-156.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 157.

Essig, Insects of Western North America, 1926, p. 550.

Male and female described. Reared in 1893 by P. H. Timberlake from a *Pseudococcus* species on *Solanum* at Riverside, California. Essig states it feeds on *Phenacoccus solani*, Ferris, in South California.

Dicrodiplosis coccidarum, Felt.

Felt, Jl. Econ. Ent., iv, 1911, pp. 548-549; loc. cit., p. 475; op. cit., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 158.

Coquillett, Proc. U.S. Nat. Mus., 22, 1900, pp. 249-250 (*Diplosis*).

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 157.

Female described. Presumably reared from a scale-insect, as it was labelled—*Diplosis coccidarum*, Mayaguez, Porto Rico, 1889, August Busck. Felt (1911, p. 475 and 1914) put it in lists of zoophagous CECIDOMYIDAE as reared from *Orthezia* and *Dactylopius*. Coquillett states that they were associated with *Pseudococcus citri*, and other very similar specimens were reared from *Saissetia hemisphaericum*, T.T. (= *coffearum*, Walker, according to Mr. Laing), from the same locality.

Lobodiplosis coccidarum, Felt.

Felt, Can. Ent., xliii, 1911, pp. 195-196; Jl. Econ. Ent., iv, 1911, p. 475; op. cit., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 165.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 192.

Male and female described. Reared by W. H. Patterson, St. Vincent, W.I., in 1911, from larvae preying on the eggs of *Pseudococcus citri*. Felt (1911, Jl. Econ.

Ent. and 1914) put it in lists of zoophagous CECIDOMYIDAE as reared from *Orthezia* and *Dactylopius* (= *Pseudococcus*).

Karschomyia cocci, Felt.

Felt, Can. Ent., xlv, 1913, pp. 304-305; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 177.

Male and female described. Reared from the sugar-cane mealybug, *Trionymus sacchari*, Ckll., collected at Central Providencia, Patillas, Porto Rico, in 1913, by D. L. Van Dine.

Acaroletes pseudococci, Felt.

Felt, Jl. Econ. Ent., vii, 1914, p. 149.

Male and female described. Reared in 1913 by Prof. H. J. Quayle from *Pseudococcus citri*, Risso, collected in Sicily.

Mycodiplosis coccidivora, Felt.

Felt, Jl. Econ. Ent., iv, 1911, pp. 549-550; *loc. cit.*, p. 475; N.Y. St. Mus. Bull., no. 202, pp. 183 and 203.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 242.

Male and female described. Reared by Prof. T. D. A. Cockerell from the ovisac of *Pulvinaria urbicola*, Ckll., taken on *Capsicum* at Kingston, Jamaica, and labelled *Diplosis coccidarum*, Ckll. Felt claims that this species is very different from the true *Cecidomyia coccidarum*, Ckll., which was from *Dactylopius* (= *Pseudococcus*). The same author (1911, p. 475) put it in a list of zoophagous CECIDOMYIDAE as reared from *Orthezia* and *Dactylopius* (= *Pseudococcus*), probably in error, however.

Mycodiplosis moznettei, Felt.

Felt, Florida Ent., v, 1922, p. 46.

Male and female described. Received from G. F. Moznette and reared in 1921 from *Protopulvinaria pyriformis*, Ckll., at Miami, Florida. It is stated that the larvae devour the eggs of the female scale and when full-grown construct cocoons underneath the scale of the host. As many as three individuals were reared from one scale.

Mycodiplosis pulvinariae, Felt.

Felt, Ent. News, xxiii, 1912, pp. 175-176; Jl. Econ. Ent., vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 202, 1918, p. 201.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 242.

Male and female described. The larvae were found by W. H. Sands and reared by W. H. Patterson from *Protopulvinaria pyriformis*, Ckll., St. Vincent, W.I.

Diadiplosis buscki, Felt.

Felt, Insector Inscitiae Menstruus, ii, 1914, pp. 122-123; Jl. N.Y. Ent. Soc., xxiii, 1915, p. 178; N.Y. St. Mus. Bull., no. 202, 1918, p. 205.

Male and female described. Evidently reared from some scale-insect as they were labelled—*Diplosis coccidarum*, Ckll., Porto Rico, August Busck. There is a key for the separation of males of this genus by Felt (1915).

Diadiplosis cocci, Felt.

Felt, Jl. N.Y. Ent. Soc., xix, 1911, pp. 54-55; Jl. Econ. Ent., iv, 1911, p. 475; *op. cit.*, vii, 1914, p. 458; Jl. N.Y. Ent. Soc., xxiii, 1915, p. 177; N.Y. St. Mus. Bull., no. 202, 1918, p. 205.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 240.

The larva, pupa, male and female were described. Reared by W. H. Patterson, St. Vincent, W.I., from larvae preying on the eggs of *Saissetia nigra* (Nietn.) on the stems of Sea Island cotton.

Diadiplosis coccidivora, Felt.

Felt, Entomologist, xlvii, 1914, p. 86; Jl. N.Y. Ent. Soc., xxiii, 1915, p. 173; N.Y. St. Mus. Bull., no. 202, 1918, p. 205.

Male and female described. Reared from a species of *Pseudococcus* on *Tephrosia hookeriana* by A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, in 1913. Also from species of the same genus on coconut and cocoa.

Diadiplosis hirticornis, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, p. 179; N.Y. St. Mus. Bull., no. 202, 1918, p. 205.

Male and female described. Reared by H. S. Smith, Sacramento, California from mealybugs, *Pseudococcus vapor*,* from Japan.

Diadiplosis indica, Felt.

Felt, Mem. Dept. Agric. India, vii, 1920, p. 6.

Male and female described. Reared from larvae preying on *Phenacoccus hirsutus*, Green, on mulberry and *Pseudococcus filamentosus* var. *corymbatus*, Green, and *Phenacoccus hirsutus*, Green, on cotton at Pusa, India, by C. S. Misra in 1918.

Diadiplosis pseudococci, Felt.

Felt, Zoologica, iii, 1921, pp. 225-226.

This species was received from Prof. W. M. Wheeler who reported the larvae as preying on *Pseudococcus bromeliae* (Bouché et auct.) (= *brevipes*, Ckll.) in a cavity of a myrmecophilous tree, *Tachigalia*, in British Guiana. The Coccids and midge larvae live in a cavity of the leaf petiole. The female, pupa and larva, which live under a web in small groups, are described.

Diadiplosis smithi, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, p. 178; N.Y. St. Mus. Bull., no. 202, 1918, p. 205.

Male and female described. Reared by H. S. Smith from cocoons produced by larvae feeding on a *Pulvinaria* on citrus at Manila, P.I.

Xiphodiplosis fulva, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, p. 180.

Larva, male and female described. Reared by A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, from *Saissetia nigra* (Nietn.) on dahlia.

Schizobremia formosana, Felt.

Felt, Ent. Mon. Mag., lxii, 1926, pp. 183-184.

Male and female described. Received from Prof. R. Takahashi, Taihoku, Formosa, as reared in 1924 from pineapple infested by a species of *Pseudococcus* which was probably the prey.

Schizobremia malabarensis, Felt.

Felt, Mem. Dept. Agric. India, x, 1927, pp. 1-2.

Male and female described. Reared from *Pseudococcus virgatus* = *Ferrisia virgata* (Ckll.) on pepper, Taliparamba, N. Malabar, 1924.

Arthrocnodax diaspidis, Kieffer.

Kieffer, Boll. Lab. Zool. Portici, iv, 1910, pp. 131-133.

Female described. Obtained from a branch of *Morus alba* infested with *Aulacaspis pentagona* (Targ.) at Acerra near Naples. This species is not mentioned in Kieffer's fascicle in Genera Insectorum 1913.

* Mr. Laing has no record of this species.

Arthrocnodax moricola, Kieffer.

Kieffer, Boll. Lab. Zool. Portici, iv, 1910, pp. 129-131.

Female described from a specimen from a branch of *Morus alba* infested with *Aulacaspis pentagona* (Targ.), Capetown. This paper contains a key for the separation of *Tricontarinia japonica*, *T. ciliatipennis*, *Silvestrina silvestrii*, *Arthrocnodax diaspidis* and *A. moricola*. This last named species is not mentioned in Kieffer's fascicle in Genera Insectorum 1913.

Arthrocnodax walkeriana, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, pp. 181-182.

Male and female described. Received from A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, reared in 1914 from a species of *Pseudococcus* on coffee. Also from a *Walkeriana*, probably *kandyense*.*

Feltodiplosis hirta (Felt).

Felt, Ent. News, xxii, 1911, p. 224 (*Endaphis*); N.Y. St. Mus. Bull., no. 202, 1918, p. 92 (*Endaphis*).

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 155. (*Feltodiplosis*.)

Male described. Reared by E. E. Green in 1904 from a *Pseudococcus* on *Mimusops hexandra*, Tangalla, Ceylon.

Adelgimyza dactylopii, Del Guercio.

Del Guercio, Note ed Osservazioni di Entomologia Agraria, Not. Prelim., Bibl. Agr. Colon., 1918, pp. 237-239; L'Agric. Colon., Florence, xiii, 1919, pp. 60-62.

Male and female described. The larvae feed at the expense of *Dactylopius* (= *Pseudococcus* sp.).

Cecidomyella aulacaspidis, Del Guercio.

Del Guercio, Note ed Osservazioni di Entomologia Agraria, Not. Prelim., Bibl. Agr. Colon., 1918, pp. 247-253; L'Agric. Col., Florence, xiii, 1919, pp. 184-190.

Male and female described, reared from larvae feeding on *Aulacaspis rosae*, L., on *Rosa* and *Rubus*.

Silvestrina chinagliana, Del Guercio.

Del Guercio, Note ed Osservazioni di Entomologia Agraria, Not. Prelim., Bibl. Agr. Colon., 1918, pp. 259-263.

Male and female described. Associated with *Diaspis* on *Rubus*, *Rosa*, etc.

Silvestrina silvestrii (Kieffer).

Kieffer, Boll. Lab. Zool. Portici, iv, 1910, p. 133 (*Arthrocnodax*); *op. cit.*, vi, 1912, pp. 173-174 (*Silvestrina*); Genera Insectorum, fasc. 152, 1913, p. 244.

Female described in 1910, male and female described in 1912. Obtained from a branch of *Morus alba* infested with *Aulacaspis pentagona*, T. T., Capetown, S. Africa (♀); as parasite of *A. pentagona* at São Paulo, Brazil (♂ ♀); and ♂ ♀ "from fruits of *Olea verrucosa*," Wellington, S. Africa.

Silvestrina silvestrii var. *cecconiana*, Kieffer.

Kieffer, Bull. Soc. ent. France, 1910, pp. 296-297.

Male and female described from fruits of *Olea europaea*, L., in Italy received from Dr. Cecconi. An anomalous male is described here.

* Mr. Laing has no record of this species. There is, however, a *Pseudococcus kandyensis*.

Androdiplosis coccidivora, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, pp. 182-183.

Described from one female reared by A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, from *Aspidiotus* sp. or *Chrysomphalus* sp., probably *orientalis*, Newst., on *Limonia alata*.

Lestodiplosis peruviana, Felt.

Felt, Ent. News, xxii, 1911, pp. 10-11; Jl. Econ. Ent., iv, 1911, p. 475; *op. cit.*, vii, 1914, p. 458.

Larva and male described. Reared by C. H. T. Townsend, Pura, Peru, from *Pinnaspis minor*.

Lestodiplosis septemmaculata, Walsh.

Walsh, Ent. Soc. Phil. Proc., iii, 1864, p. 630.

Kieffer, Monographie des Cecidomyides, 1901, p. 333.

Kieffer states that Walsh found this species feeding on a Coccid, but this is apparently an error.

Cecidomyia coccidarum (Ckll.).

Cockerell, Entomologist, xxv, 1892, pp. 180-182 (*Diplosis*); Acad. Nat. Sci. Phil. Proc., 1894, p. 419 (*Diplosis*).

Felt, Jl. Econ. Ent., iv, 1911, p. 475 (*Cecidomyia*); *op. cit.*, vii, 1914, p. 458; N.Y. St. Mus. Bull., no. 257, 1925, p. 52.

Kieffer, Genera Insectorum, fasc. 152, 1913, p. 214.

A female supposed to be the type, but not indicated on the label, is in the British Museum (Nat. Hist.). The label states that this species protrudes its exuviae from the ovisac of *Pulvinaria urbicola*, Ckll. The original description was from a fresh specimen that emerged from a box containing *Lignum vitae* leaves, on which were *Aleyrodes* and *Aonidiella aurantii*, Mask., and a young fruit of *Anoma* partly covered with *Dactylopius*. Felt (1925) states that this *Dactylopius* was *Pseudococcus virgatus*, Ckll. (= *Ferrisia virgata*, Ckll.). These midges were from Kingston, Jamaica.

Dyodiplosis generosi, Felt.

Felt, Jl. N.Y. Ent. Soc., xxiii, 1915, pp. 183-184.

Female described. Received from A. Rutherford, Royal Botanic Gardens, Peradeniya, Ceylon, reared in 1914 from twigs infested with *Howardia biclavis* (Comst.) and a species of *Aulacaspis* near *pentagona*, the latter the more abundant.

Tricontarinia ciliatipennis, Kieffer.

Kieffer, Boll. Lab. Zool. Portici, iv, 1910, p. 71; Genera Insectorum, fasc. 152, 1913, p. 145.

Male and female described. Obtained from Tokio, Japan, by Prof. F. Silvestri from branches of mulberry infested with *Aulacaspis pentagona*, Targ.

Tricontarinia japonica, Kieffer.

Kieffer, Boll. Lab. Zool. Portici, iv, 1910, p. 129; Genera Insectorum, fasc. 152, 1913, p. 145.

This is a new name for the female described by Kieffer earlier the same year as *T. ciliatipennis*, as he considered it specifically different.

Coccodiplosis pseudococci, de Meijere.

de Meijere, Tijds. v. Ent., lx, 1918, pp. 238-242.

Male, female and larva described. This species, according to Dr. Roepke (Meded. Proefstation Midden-Java, no. 23, 1916, p. 23) and P. van der Goot (*op. cit.*, no. 22, 1916, p. 40) quoted by de Meijere, feeds on *Pseudococcus adonidum*, *P. citri*, and *P. crotonis*, Green=*lilacinus* (Ckll.) at Salatiga, Java.

Other Gall Midges.

Cockerell (Entomologist, xxv, 1892, p. 180) states that Comstock (Rept. U.S. Dept. Agric. 1880) recorded the breeding of a *Diplosis* from under the scale of *Aspidiotus juglans-regiae*, Comst., in California.

H. S. Smith (Trans. IVth Internat. Congress Ent., ii, 1929, p. 217) states that a *Diplosis* species was found in 1927 in New South Wales feeding on a Citrophilous mealybug, *Pseudococcus* sp., and was transported successfully to California, where it is now being bred in large quantities in an effort to control *Pseudococcus gahani*, Green.

Mr. F. W. Edwards has shown me a slide in the British Museum (Nat. Hist.) bearing five female specimens of an unidentified gall midge. The slide is labelled—"Host: eggs of *Pulvinaria psidii* (Coccid); Locality: Coimbatore, S. India; Donor: E. Ballard."

7. List of Psyllidae, Aleyrodidae and Tingidae known or suspected to be attacked by Gall Midge Larvae.

(A) PSYLLIDAE.

Psyllid.	Midge.	Country.
<i>foersteri</i> , Flor. (<i>Psyllia</i>)	<i>Endopsylla agilis</i> , de Meijere	Holland.
<i>fraxini</i> , L. (<i>Psyllopsis</i>)	<i>Bremia</i> sp.	Europe.
<i>juncorum</i> , Latr. (<i>Livia</i>)	<i>Lestodiplosis liviae</i> , Rübs.	{ Germany,
<i>maculipennis</i> , F.Lw. (<i>Aphalara</i>)	<i>Lestodiplosis</i> sp.	England.
<i>mali</i> , Schmid. (<i>Psyllia</i>)	Cecid. sp.	Europe.
		Europe.

(B) ALEYRODIDAE.

<i>giganteus</i> , Quaint. & Baker (<i>Aleurodicus</i>)	<i>Cleodiplosis aleyrodica</i> , Felt	Panama City.
<i>vaporariorum</i> , Westw. (<i>Trialeurodes</i>)	Cecid. sp.	Surrey,
species of <i>Aleyrodes</i>	<i>Lestodiplosis</i> sp.	England.
		U.S.A.

(C) TINGIDAE.

<i>pyri</i> , F. (<i>Stephanitis</i>)	<i>Endopsylla endogena</i> (Kieffer)	Portugal.
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8. List of Coccids known or suspected to be attacked by Gall Midge Larvae.

A. IDENTIFIED COCCIDS.

Coccid.	Midge.	Country.
<i>acericola</i> (King) (<i>Phenacoccus</i>)	<i>Dicrodiplosis antennata</i> , Felt	U.S.A.
<i>adonidum</i> , Sign. (<i>Pseudococcus</i>)	<i>Coccodiplosis pseudococci</i> , de Meijere	Java.
<i>aspidistrae</i> , Sign. (<i>Pinnaspis</i>)	<i>Dentifibula obtusilobae</i> , Felt	Ceylon.
<i>aurantii</i> , Mask. (<i>Aonidiella</i>)	<i>Cecidomyia coccidarum</i> (Ckll.)	Jamaica.
<i>biclavis</i> , Comst. (<i>Howardia</i>)	<i>Dyodiplosis generosi</i> , Felt	Ceylon.

Coccid.	Midge.	Country.
<i>bromeliae</i> , Bouché (auctt.) (= <i>brevipes</i> , Ckll.) (<i>Pseudococcus</i>)	<i>Diadiplosis pseudococci</i> , Felt	British Guiana.
<i>citri</i> (Risso) (<i>Pseudococcus</i>)	<i>Acaroletes pseudococci</i> , Felt <i>Coccodiplosis pseudococci</i> , de Meijere	Sicily. Java.
<i>coffae</i> , Walk. (<i>Saissetia</i>) see <i>hemisphaericum</i>	<i>Dicrodiplosis coccidarum</i> , Felt <i>Lobodiplosis coccidarum</i> , Felt Cecid. sp.	Porto Rico. St. Vincent, W.I. Palestine.
<i>crotonis</i> , Green = <i>lilacinus</i> (Ckll.) (<i>Pseudococcus</i>)	<i>Coccodiplosis pseudococci</i> , de Meijere	Java.
<i>filamentosus</i> var. <i>corymbatus</i> , Green (<i>Pseudococcus</i>)	<i>Diadiplosis indica</i> , Felt	India.
<i>hemisphaericum</i> , T. T. = <i>coffae</i> , Walk. (<i>Saissetia</i>)	<i>Dicrodiplosis coccidarum</i> , Felt	Porto Rico.
<i>hirsutus</i> , Green (<i>Phenacoccus</i>)	<i>Diadiplosis indica</i> , Felt	India.
<i>juglans-regiae</i> , Comst. (<i>Aspidiotus</i>)	<i>Diplosis</i> sp.	U.S.A.
<i>lataniae</i> , Sign. (<i>Aspidiotus</i>)	<i>Dentifibula obtusilobae</i> , Felt	Ceylon.
<i>lichtensioides</i> , Ckll. (<i>Amonostherium</i>)	<i>Coccidomyia erii</i> , Felt	U.S.A.
<i>lilacinus</i> (Ckll.) (<i>Pseudococcus</i>) see <i>crotonis</i>		
<i>minor</i> (Mask.) (<i>Pinnaaspis</i>)	<i>Lestodiplosis peruvina</i> , Felt	Peru.
<i>nigra</i> (Nietn.) (<i>Saissetia</i>)	<i>Diadiplosis cocci</i> , Felt	St. Vincent, W.I., Ceylon.
<i>pentagona</i> (Targ.) (<i>Aulacaspis</i>)	<i>Xiphodiplosis fulva</i> , Felt <i>Arthrocnodax diaspidis</i> , Kieffer <i>Arthrocnodax moricola</i> , Kieffer <i>Silvestrina silvestrii</i> (Kieffer)	Italy. S. Africa. S. Africa, Brazil.
	<i>Tricontarinia ciliatipennis</i> , Kieffer	Japan.
<i>piperis</i> , Green (<i>Mytilaspis</i>)	<i>Tricontarinia japonica</i> , Kieffer	Japan.
<i>psidii</i> , Mask. (<i>Pulvinaria</i>)	<i>Streptodiplosis indica</i> , Felt	India.
<i>pyriformis</i> , Ckll. (<i>Protopulvinaria</i>)	Cecid. sp.	India.
<i>rosae</i> , Bouché (<i>Aulacaspis</i>)	<i>Mycodiplosis moznettei</i> , Felt <i>Mycodiplosis pulvinariae</i> , Felt <i>Cecidomyella aulacaspidis</i> , Del Guercio	U.S.A. St. Vincent, W.I. Italy.*
<i>sacchari</i> , Ckll. (<i>Trionymus</i>)	<i>Karschomyia cocci</i> , Felt	Porto Rico.
<i>salicis</i> , Linn. (<i>Chionaspis</i>) see <i>vaccinii</i>		
<i>solani</i> , Ferris (<i>Phenacoccus</i>)	<i>Dicrodiplosis californica</i> , Felt	U.S.A.
<i>ulmi</i> , L. (<i>Lepidosaphes</i>)	Cecid. sp.	England.
<i>urbicola</i> , Ckll. (<i>Pulvinaria</i>)	<i>Mycodiplosis coccidivora</i> , Felt <i>Cecidomyia coccidarum</i> (Ckll.)	Jamaica. Jamaica.
<i>uvae</i> , Comst. (<i>Aspidiotus</i>)	<i>Dentifibula cocci</i> , Felt	U.S.A.
<i>vaccinii</i> , Bouché = <i>salicis</i> , Linn. (<i>Chionaspis</i>)	<i>Bremia</i> sp.	Europe.
<i>vapor</i> (<i>Pseudococcus</i>)	<i>Diadiplosis hirticornis</i> , Felt	Japan.
<i>virgata</i> (Ckll.) (<i>Ferrisia</i>)	<i>Schizobremia malabarensis</i> , Felt	India.

* Presumably all Del Guercio's species were found in Italy, although this is not actually stated in his works.

B. UNIDENTIFIED COCCIDS.

Coccid.	Midge.	Country.
<i>Aspidiotus</i> sp. on <i>Limonia alata</i>	<i>Androdiplosis coccidivora</i> , Felt	Ceylon.
<i>Aulacaspis</i> near <i>pentagona</i>	<i>Dyodiplosis generosi</i> , Felt	Ceylon.
<i>Chrysomphalus</i> probably <i>orientalis</i> , Newst.	<i>Androdiplosis coccidivora</i> , Felt	Ceylon.
<i>Dactylopius</i> see <i>Pseudococcus</i>		
<i>Diaspis</i> sp. on <i>Rubus</i> , <i>Rosa</i>	<i>Silvestrina chinagliana</i> , Del Guercio	Italy.*
Eriococcid gall on <i>Olea</i>	<i>Cocomyza brittini</i> , Del Guercio	New Zealand.
<i>Lecanium</i> sp. on beech	<i>Coccidomyia pennsylvanica</i> , Felt	U.S.A.
<i>Pinnaspis</i> sp. on <i>Cassia alata</i>	<i>Dentifibula ceylanica</i> , Felt	Ceylon.
<i>Pseudococcus</i> sp. on citrus	<i>Diplosis</i> sp.	Australia, trans- ported to U.S.A.
<i>Pseudococcus</i> sp. on <i>Mimusoys hexandra</i>	<i>Feltodiplosis hirta</i> (Felt)	Ceylon.
<i>Pseudococcus</i> sp.	<i>Adelgimyza dactylopii</i> , Del Guercio	Italy.*
<i>Pseudococcus</i> sp. on <i>Tephrosia hookeriana</i>	<i>Diadiplosis coccidivora</i> , Felt	Ceylon.
<i>Pseudococcus</i> , sp. on pineapple	<i>Schizobremia formosana</i> , Felt	Formosa.
<i>Pseudococcus</i> sp. on coffee	<i>Arthrocnodax walkeriana</i> , Felt	Ceylon.
<i>Pulvinaria</i> sp. on citrus	<i>Microperiszia pulvinariae</i> , Felt	Manila, P.I.
	<i>Diadiplosis smithi</i> , Felt	Manila, P.I.
Scale-insect	<i>Diadiplosis buscki</i> , Felt	Porto Rico.
Scale-insect	<i>Megauchomyia africana</i> , Felt	W. Africa.
<i>Walkeriana</i> sp. probably <i>kandyense</i> (see context)	<i>Arthrocnodax walkeriana</i> , Felt	Ceylon.

* Presumably all Del Guercio's species were found in Italy, although this is not actually stated in his works.

A NEW THRIPS-EATING GALL MIDGE, *THRIPSOBREMIA LIOTHROPIS*,
GEN. ET SP. N. (CECIDOMYIDAE).

By H. F. BARNES, B.A., Ph.D.,

Entomology Department, Rothamsted Experimental Station.

It has been my privilege through the courtesy of the Imperial Institute of Entomology to examine specimens of a midge which was found predacious on *Liothrips urichi*, Karny, in Trinidad by Mr. H. W. Simmonds, and originally discovered by Mr. F. W. Urich.

Liothrips urichi feeds upon the Melastomaceous plant, *Clidemia hirta*, which has been accidentally introduced into Fiji and become a major weed.

Thripsobremia, gen. n.

This genus represents a very remarkable form, intermediate between the bifila and trifila groups of CECIDOMYINAE. Instead of the normal two or three rings of circumfila, this midge has three rings on the proximal flagellar segments, but the intermediate ring is, or appears to be, wanting on the distal segments. By reason of the irregular circumfila it approximates to the *Bremia* group and runs down in Felt's keys (1925) to *Hadrobremia*, Kieff., and *Anabremia*, Kieff. It may be distinguished from these genera by the following characters: The intermediate form of the rings of circumfila, the greatly elongated stems and necks of the flagellar antennal segments in the male, the elongated neck of these segments together with the moderately long loops of the distal ring of circumfila in the female, the third vein reaching the margin beyond the apex of the wing and the costa being interrupted at this point, and the strongly curved simple claws which are about as long as the empodium.

Thripsobremia liothropis, sp. n.

Male. Length about 1.5 mm. Antennae: 2+12, basal enlargement subglobular, bearing stout long setae and one ring of irregular circumfila (some very greatly elongated), distal enlargement piriform, bearing long stout setae and two rings of circumfila, the proximal ring, in the form of an applied thread, only appearing on the proximal segments, the distal ring with some greatly elongated loops, the stems and necks of the segments being distinctly long and narrow, stem of 10th flagellar segment being nearly three times as long as basal enlargement and about five times as long as broad, the neck being about twice as long as distal enlargement and about eight times as long as broad. Palps: 4 segments all with short setae, basal subglobular, second and third about three times as long as broad, distal segment, narrow, about four and a half times as long as broad. General colour of body orange-brown. Wings: hyaline, rather narrow and long, 3rd vein reaching beyond apex of wing, costa interrupted at this point, 5th vein forked, upper fork continuing in same direction. Legs lighter, hairy, claws all simple, strongly curved, almost at right angles, about as long as empodium. Genitalia (fig. 1): basal clasp segment, long, narrow, with short setae, distal clasp segment very short, swollen distally; dorsal lamella deeply cleft, each lobe narrowly rounded with short setae distally; ventral plate deeply cleft, each half long, very narrow, inner surface setose, outer surface hardened with small hook at apex; style long, with short setae.

Type, Cecid. 1460, 1461 (genitalia).

Female. Neck of 1st flagellar segment just over one-quarter length of basal part of segment, about three and a half times as long as broad, basal part of 8th

flagellar segment about three times as long as broad, neck of 8th flagellar segment about two-thirds to three-quarters length of basal part of segment and about six times as long as broad, terminal segment four and a half to five times as long as broad with a short protuberance distally one-quarter to one-fifth length of segment ; loops of distal ring of circumfila moderately long, loops about half the length of neck. Palps as in male. Ovipositor lamelliform. Otherwise about as in male.

Cotypes, Cecid. 1462, 1463, and 3 pinned specimens Coll. 4501 Imp. Inst. Ent.

Habit. Predacious on *Liothrips*. Trinidad, 1930, coll. H. W. Simmonds.

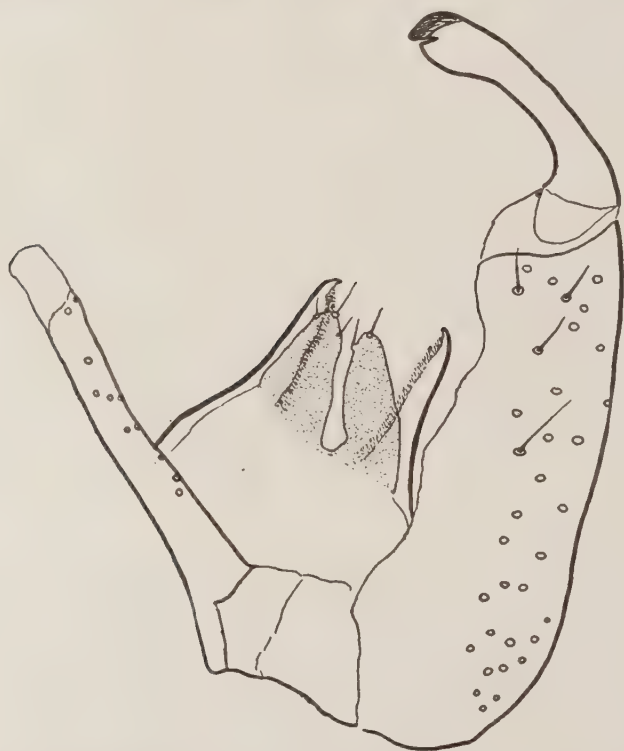


Fig. 1. *Thripsobremia liothripis*, gen. et sp. n.: male genitalia. The ventral plate has been torn apart for clarity, the clasp segments of one side being omitted.

This midge, besides being interesting because of its structural character, is noteworthy as being the second gall midge recorded as feeding on thrips. The other species is *Adelgimyza tripidiperda*, Del Guercio, which is predacious on *Phloeothrips oleae*, Costa, in Italy. This species was described (1918 and 1919) from the female and is only provisionally placed in the genus *Adelgimyza*. It may be separated from *T. liothripis* by the third vein uniting with the costa before the apex of the wing and the shorter loops of the circumfila, and the colour of the flagellar segments. It would not be surprising however if it were eventually placed in this new genus upon the discovery of the male.

GLOSSINA PALPALIS AND SLEEPING SICKNESS AT GANAWURI, PLATEAU PROVINCE, NORTHERN NIGERIA.

By A. W. TAYLOR,

Entomologist, Tsetse Investigation, Northern Nigeria.

(PLATES XI—XIII.)

It is only in recent years that the presence and extent of sleeping sickness amongst the pagan tribes on the Bauchi Plateau have been recognised. This is partly owing to the fact that endemic sleeping sickness of a very mild type with a low mortality has prevailed hitherto. The epidemic disease with a high mortality seems to be of recent origin and is probably due to the improved communications and unrestrained movement between different tribes and races throughout the Province, resulting in the introduction of new and virulent strains of *Trypanosoma gambiense*. The large labour camps at the tin mines are doubtless responsible for a good deal of this movement of population. Tsetse on the Plateau is usually scanty, as suitably heavy shade and an adequate food supply are comparatively rare. Wherever conditions permit, however, *Glossina palpalis* is present. The following report is based on a visit made by the author during November and December, 1929, to Ganawuri, where the most severe epidemic of sleeping sickness yet recorded on the Plateau was in progress. The objects of the visit were primarily an investigation into the bionomics of *G. palpalis* in this locality, and the determination of the part played by it in the transmission of the disease.

Situation, Climate and Water Supply.

The Ganawuri villages are situated along an eight mile stretch of hills and lie about 35 miles south-east of Jos in the Plateau Province (see Map, fig. 1). The line of hills on which they lie runs in a N.W.—S.E. direction, and actually forms the first step in the southern escarpment of the Bauchi Plateau. Above are the 4,000 ft. Jos highlands and 1,000 ft. below is a 10–20 mile wide plain, across which flows the River Kaduna.

This plain ends to the south-west in the Attaka and Kagoro Hills, beyond which is the escarpment proper. The average annual rainfall at Ganawuri is about 60 inches and is spread over a rainy season lasting from April to October. The dry season months present the usual features of extremes of temperature and very low humidity which characterise the Harmattan season in the Northern Provinces.

The Kaduna River rises in the hills to the north-west and flows along the foot of the Ganawuri escarpment for about three miles before turning west. At the south-east end of the hills is a small permanent stream which flows through Kakwi village and joins the Kaduna in the river plain. Between the Kakwi stream and the Kaduna River, rising in the hills and eventually joining the Kaduna, are very numerous small streams, some of the rainy season torrent type, dry for several months of the year, and others of a more or less permanent nature with their source in springs on the hill side. Many of these streams flow for the first part of their course on the river plain through deeply cut ravines, often with precipitous sides, 100 ft. or more in depth.

General Vegetation.

The distribution of forest land in the Ganawuri neighbourhood is of considerable interest and, as will be seen later, has direct bearing on the tsetse-man contact which has led to the present epidemic of sleeping sickness. An open type of woodland

forms a more or less continuous line along the base of the escarpment, but nowhere is it more than 100-200 yards wide. It is formed of large heavy shade-bearing trees (*Khaya senegalensis*, *Khaya grandis*, *Eriodendron orientale*, *Pterocarpus erinaceus*, *Chlorophora excelsa*, etc.), but there is little or no undergrowth, as the shade is utilised

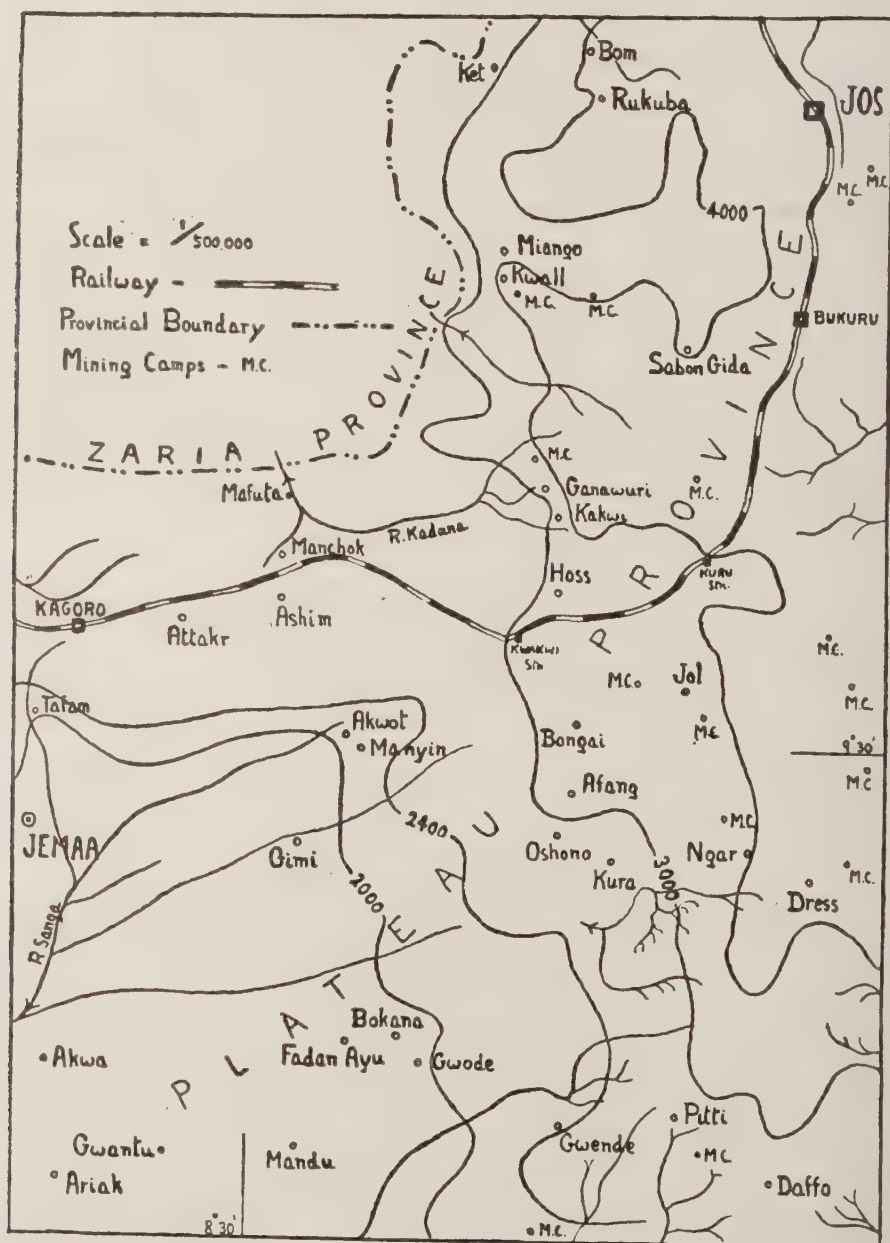


Fig. 1. Map showing part of Plateau Province, Nigeria, N.P.

for farming purposes. The hill streams, which occur every few hundred yards along the foot of the hills, vary greatly in the amount of shade which they bear. Where the banks are so steep as to prevent any attempt at clearing for cultivation the original heavy fringing forest remains. This contains heavy timber, oil palm and abundant undergrowth, with climbers and epiphytes. Along a few of these streams this line of heavy shade may extend as far as half a mile into the river plain (Plate xii, fig. 3). Where the stream banks permit, clearing has taken place and farms of yams, sugarcane and banana have replaced the original forest (Plate xii, fig. 4). An intermediate stage is common, especially right at the foot of the hills, where parts of the banks have been cleared, but a narrow belt of low trees and shrubs, not more than 4–10 feet high, borders the stream (Plate xi, fig. 4).

The hill sides, where not absolutely precipitous, are fairly thickly wooded and dense "kurumis" (small patches of forest) may centre round the springs and streams.

The river plain, at present composed of open grass and farm land, shows signs of having contained originally large areas of heavy fringing forest; there is an area of dense forest about a quarter of a square mile in extent (a *tsafi* grove preserved for religious reasons), situated 4 miles west of Ganawuri, which shows well what must have been the prevailing type of vegetation along the streams and rivers in their course through the plain. At present, however, the plain is intensively farmed by the Ganawuri and Morowa pagans, and also affords grazing for large herds of Fulani cattle. The streams flowing through it are for the most part farmed up to their banks and possess no bordering shade whatever (Plate xiii, figs. 1, 2, 3).

Population.

The Ganawuri hills are inhabited by the tribe of that name. They form a very distinct tribe, speaking a language of their own and having little communication with their neighbours. Originally a race of warriors and hunters, engaged in constant inter-tribal warfare, they have, since the coming of British administration and following the extermination of game in the district, become entirely agricultural in habit. Their farms extend across the river plain for some five or six miles to the border of the Morowa country, where the farms of this rival tribe replace those of the Ganawuris. The crops grown consist mainly of millets, grasses (*Digitalia exilis*, *Eleusine corocana*, etc.) and root crops (koko-yam—*Colocasia antiquorum* and *Plectranthus* sp.). The population is distributed along the Ganawuri hills in a long series of villages, a few of which are built in the denser parts of the woodland at the foot of the hills; most of the villages, however, are situated on the face of the escarpment in situations presumably chosen solely for defensive purposes and in some cases are as much as 600–800 feet above the plain. The water supply of these hill villages is obtained from the springs and streams around which the houses are usually grouped. The Ganawuri tribe numbered 5,052 at a census taken in 1927. Since this date sleeping sickness has taken heavy toll and the present population is certainly smaller than this figure. Kakwi, one of the largest of the villages, where the epidemic originated, has been practically depopulated, and the same thing has been happening in a lesser degree in several of the other villages. There is a small Hausa (Mahomedan) trading settlement at the base of the escarpment with a total population of nearly one hundred. During the rains and early dry season large numbers of cattle are grazed on the river plain by the nomadic Fulani, whose encampments are scattered over the plain.

Trypanosomiasis amongst the Ganawuri.

Attention was first directed to Ganawuri by Dr. W. B. Johnson, late of the Tsetse Investigation, who visited the place in October 1928 and reported the presence of tsetse and sleeping sickness. Following this report, treatment was commenced

by Dr. F. Kane in November 1928, and continued by Dr. J. C. Paisley in January and February 1929. During this period over 2,000 cases of sleeping sickness were diagnosed and treated. Clinics were held in June 1929, by Dr. C. W. Hope-Gill and in November–December 1929, by Dr. J. C. Paisley, and in these visits a further 600 cases were treated. Between January and May 1930, 649 new cases were treated by Dr. J. H. Pasqual.

A factor which renders effective treatment of the pagan Ganawuris extremely difficult is their reluctance to complete the full course of injections, and the result of this is clearly seen in the large percentage of relapses coming up for treatment in the later clinics in 1929. In this matter the Mahommedan Hausas and Fulani from the Ganawuri district form a striking contrast to the pagans, as they invariably complete their course of treatment and apparently obtain permanent cures. The numbers quoted above indicate a total infection rate amongst the Ganawuri pagans of considerably over 50 per cent. The true figure is probably nearer 75 per cent., as new cases are coming in steadily.

From reports by the pagans themselves, sleeping sickness appears to have been endemic in the district for as long as can be remembered. The disease appears to have been of a mild type with a low mortality. The present epidemic is quite recent, however, and the symptoms are much more severe than in any previous type of the disease in this locality. Local report attributes the origin of the epidemic to a man from Jemaa (a notorious sleeping sickness centre south of the Plateau), who settled at Kakwi about six years ago and died there from trypanosomiasis.

Bionomics of *G. palpalis* at Ganawuri.

The only species of tsetse found at Ganawuri is *G. palpalis*. *G. tachinoides* is not known to occur on the high ground of the Bauchi Plateau, and the *G. morsitans* group is entirely unrepresented. The shade suitable for *G. palpalis* is of very limited extent, and the majority of this shade is confined to very short stretches of hill streams on and at the extreme base of the Ganawuri escarpment. These streams, moreover, are not permanent, many of them drying up entirely during the Harmattan season except for a few yards at their source, usually in a village high up on the hill side. There are, as has been said, two main permanent streams in the district. The first is the Kaduna River, to the north-west. This is of no importance as a tsetse focus, as there is no shade on the river itself, the banks being grass or farm land (Plate XIII, fig. 1). The second stream flows through Kakwi village at the south-easterly end of the escarpment. This stream flows through a gorge at Kakwi (Plate XIII, fig. 3), where there is the heaviest forest found along the Ganawuri escarpment, and it is on this mile-long stretch of stream that *G. palpalis* is most numerous. In fact, it is the only true primary focus of the fly in this district. *G. palpalis* is found during the wet season all along the base of the escarpment at the various village streams, which are then in flood, and follows the shade lines up the hill sides and so into the villages. At the time of the present visit (November–December, 1929) fly was taken on four of the hill streams (Nos. i, iii and vi) which were still flowing, as well as at the Kakwi primary focus. Tsetse was found to be most numerous on the hill streams at path crossings and village watering places; these points frequently possess but scanty shade, yet tsetse is readily found, whereas densely shaded ravines containing abundant water but unfrequented by man and domestic animals may be entirely tsetse-free.

It is of interest to note that on two occasions early in the visit, *G. palpalis* was taken on streams 600–800 ft. above the plain at watering places of two hill villages (Plate XI, fig. 3). The shade at this height is much lighter than on the same streams

at the foot of the hills and there is little protection against the dry Harmattan wind. These flies were evidently survivors from the wet season spread; repeated search during the last month of the visit failed to discover any tsetse on streams above the level of the plain. Late in the dry season it is very probable that tsetse all but disappears from the hill streams, though very scanty fly may persist on streams i and ii at village watering places at the foot of the hill (Plate XI, fig. 4).

TABLE I.

Abundance, Sex Ratio and Pregnant Females in G. palpalis at Ganawuri.

Locality.	Total Catching hours.	Total number taken.	Abundance (total flies per boy-hour).	Female percentage.	Pregnancy percentage.
Stream i ...	24.5	82	1.58	37.8	41.9
Stream ii ...	33	144	2.41	51.0	43.2
Stream ii (600 ft. above plain) ...	8	3	0.1	—	—
Stream iii ...	4	3	0.56	—	—
Stream vi ...	3	4	1.33	—	—
Kakwi ...	30.5	261	3.26	49.0	25.0

The figures given in Table I indicate the scarcity of tsetse at Ganawuri, even at the Kakwi focus where optimum conditions for the fly exist. The greatest numbers of fly taken on the Ganawuri hill streams were caught on streams i and ii at the foot of the hills at watering places which were being used at the time of the visit by two large villages, Danse and Gwantara. The shade at these points was scanty, being formed almost entirely by a prickly shrub (*Pandanus utile*) which did not exceed 10 feet in height and formed a thin border along the stream banks. On streams iii and vi *G. palpalis* was taken in very small numbers in heavy or moderately heavy fringing forest with high shade, at path crossings.

From Table I it is seen that the sex ratio of *G. palpalis* taken at Ganawuri shows no unusual features. Breeding was going on at the Ganawuri hill streams i and ii as well as at Kakwi.

The food supply of *G. palpalis* on the Ganawuri streams, except that at Kakwi, is derived entirely from man and domestic animals. The latter class includes sheep, goats, dogs and horses. Of these the sheep and goats are most numerous and offer most opportunities to the tsetse, as they graze on the hill sides and drink at the streams, often at the base of the hills where fly is most numerous. The herds of Fulani cattle which graze on the river plain seldom or never come into contact with tsetse, as they are watered at shadeless streams some distance from the hills. According to the Ganawuri pagans, game was originally very abundant in the district, and the large numbers of buffalo heads and other hunting trophies still kept in the villages support their statement. At present game is entirely absent, the probable factors leading up to its disappearance being the great increase of farm land, the clearing of the streams on the plain, and the former extensive hunting operations by the pagan tribes. On the high ground above the escarpment a few leopard occur, while *Hyrax* and occasional monkeys (*Erythrocebus* sp.) are sometimes seen on the cliffs above the villages. None of these animals ever comes into contact with tsetse on the streams at the escarpment base.

Aquatic reptiles (probably *Varanus* sp.) are present only in the Kakwi stream, so that *G. palpalis* at all the Ganawuri villages save Kakwi is wholly mammalian in its diet. This is most unusual for this fly in Northern Nigeria, as it normally obtains a considerable proportion of its food from reptiles (chiefly *Varanus* and crocodile). Lloyd & Johnson (1923) found 22 per cent. of recognisable blood to be reptilian in 552 *G. palpalis* examined by them in various localities in the Northern Provinces.

TABLE II.

Blood Content of G. palpalis examined at Ganawuri.

Locality.	No. examined.	Proportion containing recognisable blood.	No. containing reptilian blood.	No. containing mammalian blood.	Mammalian blood.	
					Sheep and goat.	Man and (dog).
Stream i ...	82	31=37.8%	Nil	31=100 %	12	19
Stream ii ...	147	45=30.6%	Nil	45=100 %	29	16
Stream iii ...	3	1=33.3%	Nil	1=100 %	1	—
Stream vi ...	4	1=25.0%	Nil	1=100 %	—	1
Kakwi ...	141	39=27.6%	5=12.8%	34= 87.2%	19	15

Table II records for each locality the numbers of *G. palpalis* examined which were found to contain recognisable blood, and the class into which the blood falls. The mammalian blood was found to fall into two very distinct groups readily distinguished by the great difference in size of the erythrocytes. The method of estimation is that described by Lloyd, Johnson & Rawson (1927). The small red cell type is entirely derived from the sheep-goat group, while the large red cell type belongs to the class which includes man, monkey and dog. In the absence of monkeys the majority of the bloods falling into the latter class must be human, as dogs, though numerous in the villages, seldom come into contact with tsetse during the dry season.

Trypanosome Infection Rate in *G. palpalis*.

One of the main objects of the present visit was the determination of the mode of transmission of the disease. The very unusual infection rate, together with the scarcity of tsetse, led to doubts as to whether the normal mode of transmission by cyclically infected tsetse was being superseded by mechanical transmission, possibly by a biting fly other than *Glossina*. It was considered that dissection of locally caught *G. palpalis* might throw light on the problem. Unfortunately it was not found possible to obtain large numbers of the fly, but the results given below are sufficient to indicate the probable infection rate in the fly. The absence of game and aquatic reptiles, and the freedom of domestic animals from trypanosome infections* simplifies the identification of developmental trypanosomes in the tsetse dissected, as all infections can be diagnosed with certainty as *T. gambiense*.

* The two main grounds for this statement are as follows: (1) That if game trypanosomes were being maintained in the domestic animals, proboscis infections of *T. vivax* and *T. congolense* would certainly have been seen during the dissections; and (ii) the fresh bloods of 45 sheep and goats from the villages were examined and found to be negative.

TABLE III.

T. gambiense Infection in *G. palpalis* examined at Ganawuri.

Locality.	Number examined.	Total infection rate.	Immature infections (gut only infected).	Mature infections (gut, proventriculus, salivary glands and hypopharynx infected).
Stream i	82	4.9 per cent.	4=4.9 per cent.	Nil
Stream ii	147	2.7 per cent.	3=2.0 per cent.	1=0.4 per cent.
Stream iii	3	33.3 per cent.	1	Nil
Stream vi	4	Nil	Nil	Nil
Kakwi	141	Nil	Nil	Nil

Table III records the results of six weeks' dissection of daily catches of *G. palpalis* from the Ganawuri localities. In a number of flies dissected totalling 236, nine (3.8 per cent.) were found to contain trypanosomes. One of these infections (0.4 per cent.) was mature, gut, proventriculus, salivary glands and hypopharynx being infected. The remainder consisted of immature infections confined to the gut. This infection rate, approaching as it does the maximum infectivity to tsetse of certain *T. gambiense* strains, is believed to be the highest infection rate recorded for *T. gambiense* in wild flies. It must be remembered that the dissections were carried out in the early dry season, when breeding was relatively rapid and the life of the fly short. It is probable that during the rainy season, when conditions for the tsetse are more favourable, the life of the fly longer, and contact with man even closer, the infection rate in the tsetse would be increased.

The figures quoted above do not include dissections of *G. palpalis* from the Kakwi stream. At this focus the abundance of shade and presence of an alternative source of food in aquatic reptiles results in a set of conditions widely different from those on the Ganawuri hill streams. A total of 141 *G. palpalis* from the Kakwi focus were dissected, and all proved negative. No *T. grayi* infections were found here, though in *G. palpalis* from Manchok, 12 miles from Ganawuri, where the streams contain reptiles, 3.5 per cent. of the flies dissected were infected by trypanosomes belonging to the *T. grayi* group.

Conclusions and Methods adopted.

It has been shown above that the absence of game and aquatic reptiles, the normal buffers between *G. palpalis* and man, has resulted in the fly obtaining a large proportion of its food from man. There is also in the district localisation of shade suitable to *G. palpalis* in, and in the very near vicinity of, the Ganawuri villages. The combination of these two factors has produced an extraordinary degree of intimacy of contact between tsetse and man, and the introduction of a virulent strain of *T. gambiense*, probably from Jemaa, has resulted in the present severe epidemic. Transmission of the disease is by cyclically infected *G. palpalis*, and the high infection rate in the fly makes up for its low rate of abundance. A brief review of methods for dealing with the epidemic follows.

As in other sleeping sickness centres in Northern Nigeria, treatment alone has merely served to check the epidemic temporarily. In the absence of compulsory examination and treatment camps at Ganawuri only a very small proportion of the cases can be induced to attend the clinic regularly for the full course of treatment. This has resulted in a very large percentage (40-60 per cent.) of relapses.

Here, as elsewhere, in order effectively to combat the disease it is necessary to supplement treatment by adopting adequate measures to break the existing tsetse-man contact. Protective clearing is the normal method adopted to attain this end. At Ganawuri, however, clearing was found to be impracticable. To ensure immediate success it would have been necessary to undertake the clearing of the Kakwi stream, all of the very numerous hill streams along eight miles of the escarpment, and a large amount of the bush in and around the villages. The cost of clearing and maintaining such an area would have been prohibitive, even if labour could have been obtained. Furthermore, the pagans themselves would not agree to any extensive clearing, partly on the ground that the trees on the hill sides protected their villages from lightning, and partly because of the fear that the many sacred groves near the villages and on several of the streams would be interfered with.

The alternative to clearing was the complete removal of the population from the hills to the tsetse-free river plain. The great difficulty in effecting this move was the strong sentimental and religious attachment of the Ganawuri pagans to their hill villages. From every other standpoint such a move had everything to recommend it, as the Ganawuri farms are on the plain and there is abundant and excellent water to be had.

Suitable sites, at a minimum distance from the hills of $2\frac{1}{2}$ miles were chosen. Thanks to the interest taken in the scheme by the Resident of the Plateau Province, Mr. H. Hale Middleton, visits to Ganawuri were made by Capt. Baker and Mr. C. R. Walker of the Political Department, Jos, who visited the proposed sites with the village heads and spent a great deal of time in endeavours, eventually successful, to persuade the headmen of the tribe to move their villages. Building on the new sites commenced in January 1930, and by April most of the new villages were completed. Unfortunately, an early rain did damage to some of the unfinished huts, but on a visit to Ganawuri in early May it was clear that the majority of the population was then living in the new villages, situated at distances varying from two to four miles from the hills and scattered over the river plain on the banks of the River Kaduna and its tributary streams. All of these streams are completely tsetse-free. It is confidently anticipated that this breaking of the previous tsetse-man contact, together with the continuation of the treatment of existing sleeping sickness cases will bring the epidemic to a rapid close.

References.

1. JOHNSON, W. B., & LLOYD, L. (1923) First Report of the Tsetse-fly Investigation in the Northern Provinces of Nigeria.—Bull. Ent. Res., xiii, pp. 373–396, 5 pls., 1 map.
 2. LLOYD, L., JOHNSON, W. B., & RAWSON, P. H. (1927) Experiments in the Control of Tsetse-fly.—Bull. Ent. Res., xvii, pp. 423–455, 2 pls. 13 charts.
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EXPLANATION OF PLATE XI.

- Fig. 1. Ganawuri Rest House : Danse and Gwantara villages on hills in background.
„ 2. Gwantara village, showing moderate to heavy shade on the escarpment face.
„ 3. Danmameroi village, 800 ft. above the river plain, showing heavy shade
„ along hill streams forming wet-season lines of tsetse spread.
„ 4. Stream II at village watering place at the foot of the hills : *G. palpalis*
present.



1.



2.



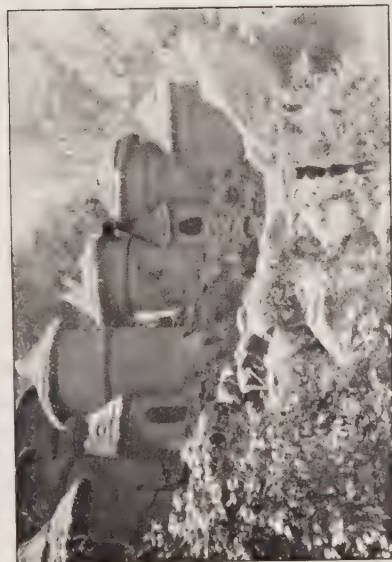
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4.

EXPLANATION OF PLATE XII.

- Fig. 1. Ganawuri huts.
- „ 2. Sleeping Sickness patients, Ganawuri.
- „ 3. Stream III, 800 yards from hills: very scanty clearing on stream-banks
for yam farms: *G. palpalis* present.
- „ 4. Stream III, one mile from hills, showing extensive clearing for farms:
G. palpalis absent.



1.



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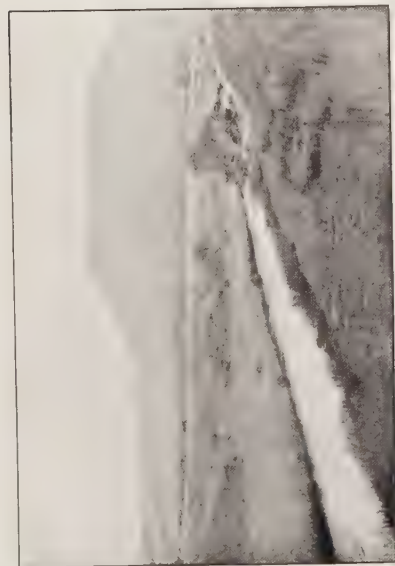
3.



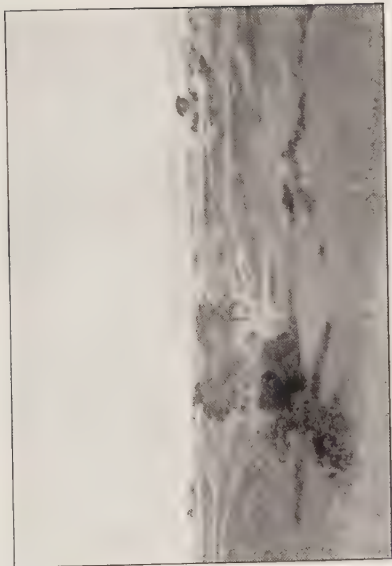
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EXPLANATION OF PLATE XIII.

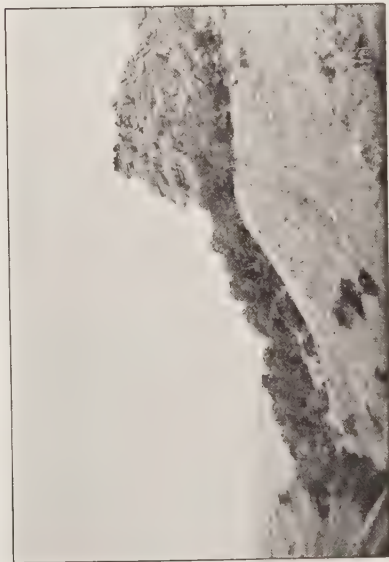
- Fig. 1. Ganawuri hills with R. Kaduna in foreground.
„ 2. Looking south over the river plain.
„ 3. Kakwi crag, showing heavily forested stream flowing through gorge into the river plain.
„ 4. North-eastern end of the Ganawuri hills showing R. Kaduna, and the localisation of forest along the foot of the hills.



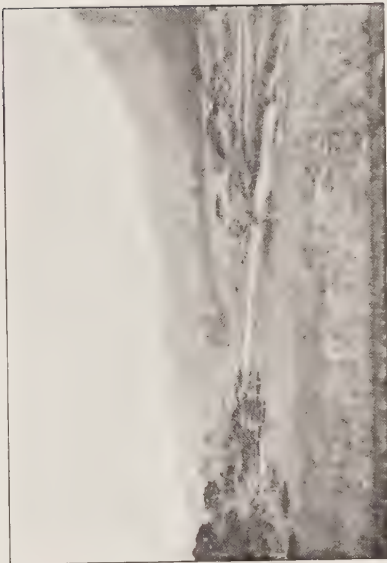
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CARABUNIA MYERSI, WATRST. (HYM., ENCYRTIDAE), A PARASITE
OF NYMPHAL FROGHOPPERS (HOM., CERCOPIDAE).*

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1. Introduction.

The remarkable scarcity of insect parasites or parasitoids attacking the CERCOPIDAE is clearly shown in the work of Williams (1921) on the biology of the Trinidad cane-froghopper (*Tomaspis (Monecphora) saccharina*, Dist.). The list of records is indeed apparently exhausted by the mention of three obscure Chalcidoid egg-parasites, certain Drosophilid fly-larvae and the remarkable *Carabunia*, which is the subject of the present paper. The egg-parasites are obscure, and may or may not be regularly associated with froghoppers. Their great scarcity has hitherto prevented any very exact studies of their life-history and host-range. The Drosophilid maggots are in some cases apparently merely inquilines in the spittle-masses, in others however more or less directly parasitic on the nymphs.

In the early part of 1925, during general studies on the local Homoptera at the Harvard Tropical Biological Laboratory, at Soledad, near Cienfuegos, Cuba, abundant nymphal material was obtained of a froghopper, *Clastoptera* sp., which proved to be so heavily parasitised that repeated attempts to rear the adult were entirely unsuccessful (Myers, 1928, p. 124). The Encyrtid wasp responsible for this heavy mortality was later (1928) described by Waterston as *Carabunia myersi*, a new genus and species, of the greatest systematic and morphological interest. In the course of the investigation undertaken by the Imperial Institute of Entomology into the biological control of West Indian insect pests, the biology of *Carabunia* was studied in more detail during the wet season of 1929, with special regard to its possible utilisation against the Trinidad cane-froghopper. It may be definitely stated at the outset, that this hope was entirely disappointed, and this may in part explain the incomplete character of the study here presented. *Carabunia* shows so many exceedingly curious features in its life-history, especially during the larval stadia that it merits a detailed study by a leisured specialist in histological technique.

2. The Host of Carabunia.

The 1925 material was reared from *Clastoptera* nymphs occurring abundantly on the introduced ornamental shrub, *Acalypha wilkesiana*, in the Harvard Botanical Garden at Soledad, Cuba. A search was begun on the same bushes on the 26th July 1929, and in the course of the next few days every specimen of *Acalypha* in the garden was examined and beaten for adult froghoppers with no success until the 2nd August, when one imago of *Clastoptera undulata* was obtained. Spittle-masses containing newly-hatched nymphs were not found until the 9th August. These were upon an *Acalypha* near the original bushes and on an adjacent plant of *Melastoma molkenboerii* from Java. In three more days spittle-masses began to appear in comparative abundance, not only on the *Acalypha*, but also on *Hibiscus rosa-sinensis*, a common but introduced hedge-plant. There were often as many as three nymphs in one spittle-mass; but all of about the same size and age (?), whereas in *Tomaspis bicincta fraterna* where more than one nymph is present, there is usually very great variation in age and size. On the 16th August plentiful spittle-masses were found on *Malvaviscus arboreus*. In the meantime a number of masses

* Contributions from the Farnham House Laboratory, Imperial Institute of Entomology, No.2.

had been sleeved and had produced adult froghoppers *Clastoptera undulata*, Uhl. Spittle-masses continued abundant throughout August and until the second week in September. They could still be found thereafter, though less plentifully, up to the 8th November, when the last observations were made. This period from the 9th August to the 9th November is one of comparatively heavy rainfall. The 1925 observations, on the other hand, were made chiefly in February, which is, for Cuba as a whole, the driest month in the year, though not quite so at Cienfuegos (Fassig, 1925). At that time spittle-masses were first collected on the 18th February, and from material sleeved on the 25th some *Carabunia* had emerged by the 1st March. Emergence of the parasites continued until the 6th March. A special search on the 12th April revealed no traces of spittle or of adults. When one considers that the wet months in Santa Clara Province are May to October inclusive (Fassig, Diagram 1) the seasonal incidence of *Clastoptera undulata*, as pieced together from these scattered observations, appears curious in the extreme. There would seem to be two peaks of nymphal abundance, one near the middle of the wet season and the other near that of the dry. The cane-froghopper (*T. saccharina*) in Trinidad, at least under cane-field conditions, and apparently also its relative (*T. bicincta fraterna*) in Cuba, in very marked contrast on the other hand, pass through a succession of generations during the wet months, with abundant nymphs; and spend the dry season almost entirely in the egg. These are obviously features of the deepest significance in a consideration of biological control.

The plant hosts of *Clastoptera undulata* at Soledad may be listed as follows, in order of abundance of spittle-masses found thereon:—

Acalypha wilkesiana.

Hibiscus rosa-sinensis.

Malvaviscus arboreus.

Acalypha godseffiana.

A. marginata.

Melastoma molkenboerii, one case only.

Bauhinia hookeri, once only. Determined from nymph.

Bixa orellana, once only.

Of these, only the third, *Malvaviscus*, is indubitably indigenous in Cuba, but in any case, all the plants listed were growing under cultivation in the Botanical Garden. In spite of very extensive collecting, especially by sweeping in 1925, only one specimen (an adult) of *C. undulata* was taken outside the limits of the Botanical Garden. This was on the 11th September, in a hedge between a cane-field and a tiny patch of forest reserve, and only a few hundred yards from the garden. The specimen was beaten from *Bursera simaruba* and *Guazuma tomentosa* growing together. Adults were never common, however, even in the Garden.

It is curious that spittle-masses were never found on the *Hibiscus rosa-sinensis* hedges, of which there were long stretches on the estate, but only on more or less isolated bushes in the Garden. These hedges were frequently clipped—a procedure liable to destroy eggs in the terminal branches. There were hedges of *Acalypha* also, but again all the material was obtained on isolated bushes, growing less artificially. This, however, was less remarkable, since the proportion of *Acalypha* growing as a hedge was much less than that of *Hibiscus*. Another species of *Clastoptera* does occur plentifully on trimmed hedges of the same *Hibiscus* in Trinidad. *C. undulata* seems definitely to prefer host-plants in the shade. Numerous *Acalypha* bushes growing in the open yielded none.

The second observed host of *Carabunia* was a species of *Clastoptera* infesting very heavily the twigs of the introduced shade-tree, *Casuarina equisetifolia*, planted in the public square at Central Jaronú, a large sugar-cane estate in the province of Camagüey, on the north coast of Cuba. Torrential rains during the ten days (22nd

October—1st November) of our stay prevented sleeving; and so no adults of this *Clastoptera* were obtained for determination. In addition to the tall trees of *Casuarina*, there were some closely clipped hedges of the same plant, which yielded, in contrast to the trees, no spittle-masses at all. Curiously enough, though *Casuarina* is grown at Soledad, in Santa Clara Province, no froghoppers were there collected on it.

A third host of *Carabunia* was discovered in the mountains of Haiti, but as no adults of the parasite were reared, it is not certainly conspecific with the Cuban genotype. The larvae, however, appeared identical. The host was a large, pale-coloured *Clastoptera* nymph (H.122, 133) on a beautiful, red-flowered fuchsia (*F. triphylla*, L.) growing in subalpine scrub on Morne Tranchant at an elevation of about 6,000 feet, and on Morne Noire at about 5,500. The masses of spittle, inhabited by three or four nymphs, were almost invariably in curled leaves. It would appear that these are pseudo-galls caused by the insect, since adjacent, uninfested leaves of the same age were straight.

The following other *Clastoptera* nymphs, unfortunately not determined, were examined for *Carabunia* with negative results:—

In British Guiana: D29, spittle-masses abundant on twigs of a bushy tall *Jussieuia* growing in and on the edges of water in cane-fields fallowed by flooding; 35 nymphs of various ages were dissected. Plantation Providence, Demerara, 20th March 1929.

In Trinidad: On *Hibiscus rosa-sinensis* (21st, 24th November, 9th December 1928, 27th February 1929, T205, 252), a small, pale-coloured *Clastoptera* nymph; 35 dissected. Drosophilid larvae are frequent inquilines—sometimes as plentiful as the nymphs.

In Cuba: C210, dark brown (anteriorly) and white *Clastoptera* nymphs on unknown shrub at about 1,000 feet elevation, above San Blas, Trinidad Mts., 17th September 1929.

In Haiti: H47, small black and white *Clastoptera* nymphs on *Croton linearis*, a small, aromatic shrub along path up Morne L'Hôpital between 700 and 1,000 feet elevation, 28th November; H61, pale-coloured, and dark-and-pale *Clastoptera* nymphs in some numbers on a trackside weed, *Sida* sp., at about 1,500 feet on Morne L'Hôpital, 1st December; H121, a very small, contrasted black and white *Clastoptera* nymph on unknown shrub in subalpine scrub on summit of Morne Tranchant at about 6,500 feet elevation, 14th December.

In Jamaica: During January and part of February 1930, Mr. A. Pickles, Entomologist to the Trinidad Froghopper Investigation Committee, examined in our company *Clastoptera* nymphs from pimento (*Pimenta officinalis*), from *Casuarina equisetifolia* and from *Dodonaea viscosa* var. *angustifolia*, none of which yielded *Carabunia*.

Finally, froghopper nymphs of other genera, notably *Tomaspis* (*T. bicincta* *fraterna* in Cuba, J. G. M.; and *Tomaspis* sp., near *bicincta*, in Jamaica, J. G. M. & A. Pickles), *Lepvrontia* (in Cuba), *Leocomia* in Jamaica (A. Pickles), were dissected in varying numbers, depending entirely on the populations found. No case of parasitism of *Carabunia* was discovered. At Soledad a total of 300 nymphs of various ages of *T. bicincta fraterna* was examined from grasses less than a mile from the Botanical Garden where *Carabunia* was parasitising *Clastoptera undulata* so heavily. This seemed to indicate that *Carabunia* is not a parasite of *Tomaspis*. To test the matter further, reared females with a male of *Carabunia* were caged with *T. bicincta* nymphs of nearly all instars save the last, which was considered too large. The little wasps dashed about the plants with a quick, jerky, nervous gait. It is to be noted that the *Tomaspis* spittle has very much larger versicles and stands out much further from the body of the nymph. It is also far less slimy than that of *Clastoptera*, which tends little more than to cover the nymph, whereas

in *Tomaspis* it buries the owner. The spittle "mesh" of a first instar *Tomaspis* nymph is about equal to that of a last instar *Clastoptera*. In spite of these very great physical differences the *Carabunia* ran over the *Tomaspis* spittles with no difficulty, palpating them with the antennae. A small mass containing a first instar nymph was stabbed repeatedly, whether by the same or a different female I do not know. I could not see the ovipositor enter the nymph, but I watched the latter closely for any squirm, and saw none. Larger spittle-masses were apparently not stabbed; and it was certainly only in a few of them that the nymph could have been reached. In 24 hours all the *Carabunia* were dead. The frog hopper nymphs were left to develop for another three days—a period suggested by the life-history as indicated below—and were then dissected. No traces of *Carabunia* larvae or eggs were found.

It would thus seem that *Carabunia* is not actually a parasite of *Tomaspis* nor is it likely to become so if introduced into Trinidad. The only hosts so far known are the nymphs of *Clastoptera undulata*, Uhl., and *Clastoptera* sp., on various ornamental shrubs and trees in Cuba, and of *Clastoptera* sp. on *Fuchsia* in the mountains of Haiti.

3. Incidence of Parasitism.

In *Clastoptera undulata* nymphs, in February 1925, the rate of parasitism was roughly estimated at 100 per cent. No spittle-masses sleeved yielded anything but *Carabunia*.

In 1929, on the same host at the same locality, collections of nymphs were dissected, and more exact figures obtained, but these were always limited, of course, by the number of nymphs obtainable.

C79, 43 nymphs from *Hibiscus*, 12th August 1929, 65.1 per cent. parasitised.

C148, 67 nymphs from *Acalypha* and *Hibiscus*, 28th August 1929, 71.6 per cent. parasitised.

C67, 6 first (?) instar nymphs on *Melastoma molkenboerii*, 9th August, not parasitised.

C324, nymphs on *Hibiscus* and *Bixa orellana* noticed 8th November to be "heavily parasitised."

In the above cases, nymphs of all ages were collected and dissected in the proportions in which they were found. Such random collections naturally contained a number of young nymphs, which, as we shall see later, would not be attacked by *Carabunia* at that stage. When material for rearing *Carabunia* was desired, only last (5th) instar nymphs were taken, and these seemed so heavily parasitised that I estimated over 90 per cent. were attacked. An analysis of the two random collection figures above into those for larger and smaller nymphs, does not, however, show such a great divergence, and the final parasitism, during the period of observation, was probably not higher than 80 per cent. of the whole Garden population.

With a view to obtaining a more definite notion of the final infestation, at Central Jaronú, in October, when the Casuarina *Clastoptera* was being studied, only ultimate instar nymphs were taken for dissection. Of 45 such nymphs dissected on 23rd and 24th October (C275, 276) all but one were parasitised, the rate being thus 97.8 per cent.

Of the *Fuchsia Clastoptera* only scanty material was available, as follows:

H122, Morne Tranchant, 14th December, on *Fuchsia*, 12 large nymphs, 10 or 83.3 per cent. parasitised.

H133, Morne Noire, 15th December, on *Fuchsia*, 5 large nymphs, all parasitised.

These sets of figures, scanty though they unavoidably are, present certain features of great ecological interest. The Fuchsia *Clastoptera* was the only one living under approximately primitive conditions (somewhat affected by introduced grazing animals). The plant-host is an autochthonous species, the *Clastoptera* and the *Carabunia* almost certainly indigenous. In Cuba, on the other hand, no *Carabunia* was found in any indigenous plant association. *Clastoptera undulata* occurred in an old-established Botanical Garden.

The most highly altered conditions were those surrounding the Casuarina *Clastoptera* at Jaronú, since the whole estate, of which these trees ornament the bately square, was converted from heavy forest into sugar-cane only some ten years ago, during the post-war sugar boom—the “Dance of the Millions.”

On general considerations one would have expected the greatest balance between parasite and host to prevail under the more primitive Haitian conditions, less balance in the old garden environment and still less in the ecological upheaval at Jaronú. And a balance would surely mean a smaller toll of the host than 80 per cent. Unfortunately, the figures obtainable are too low, especially in the Haitian host, to allow a fair comparison. They tend, however, to show that the parasitism is heaviest in the Jaronú *Casuarina* host, as might be expected; but lower at the Soledad Botanical Garden than in the Haitian Mountains.

4. Effect on the Host.

The older parasitised nymphs are of an entirely different shape and size from normal ones of the same instar. This difference I thought at first to affect also the dimensions of the head and thorax, as in ants parasitised by *Mermis* worms, but a series of measurements showed no significant difference. It is the abdomen which is most altered, and this is profoundly affected. The following may be taken as average measurements of fifth instar nymphs of *Clastoptera undulata* :—

Parasitised nymph, abdomen 3 mm. wide, 3·4 mm. long.

Normal nymph with head and thorax of same size, abdomen 2·0 mm. wide, 2·0 mm. long.

The abdomen of parasitised nymphs is gigantic and dome-shaped, the whole body straight along the ventral line, but dorsally tremendously swollen.

The parasitised nymphs seem to behave normally until after the emergence of the parasites, which is effected by one or more great holes through which the intestines may in some cases protrude. In captivity it was found that nymphs from which one or more *Carabunia* had thus emerged might crawl considerable distances, but did not live more than six hours.

The host's alimentary system, though crowded out, is recognisable in all its parts, and apparently functional until actual perforation of the skin by the emerging adult parasites.

5. The Egg of *Carabunia*.

The egg (fig. 1, *a*) is laid in the young nymph, and in the example drawn was floating loose among the abdominal organs, but may have become detached during dissection. It is colourless or whitish, with a very thin chorion bearing no very evident sculpturing. It resembles considerably in form that of *Encyrtus infidus* (Parker, fig. 21, after Silvestri). The pedicel, which is slightly twisted, is about half the length of the egg itself. Total length (as drawn) including pedicel: 0·352 mm.

The only example found lay among the intestinal folds of a small nymph (*Clastoptera undulata*), probably of the second instar, in a large spittle-mass with several larger (3rd or 4th instar) nymphs.

The egg stage lasts about a day.

6. The Larva of *Carabunia*.

All descriptions were drawn up from *Carabunia myersi* material dissected from the type-host in the type-locality.

There may be as many as 12 larvae or as few as one, in the abdomen of one host. The average of 28 cases was 3.7. The larvae are confined to the abdomen, where

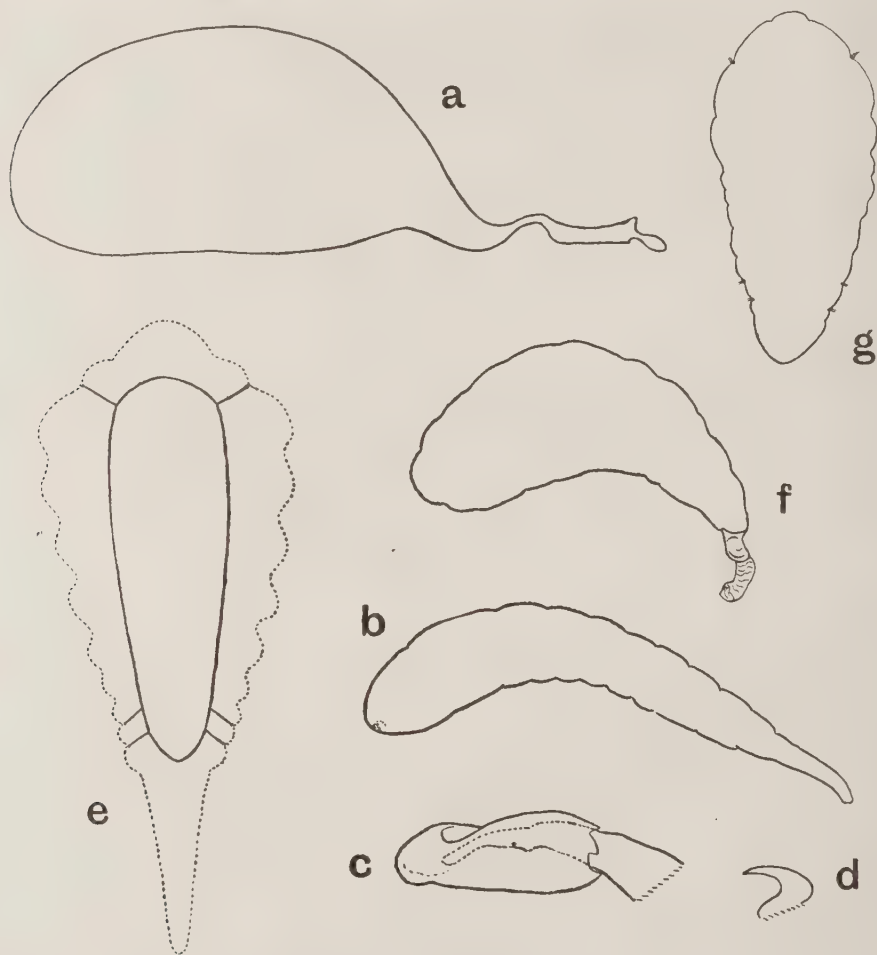


Fig. 1. *Carabunia myersi*, Watrst.: a, egg; b, larva, 1st instar; c, egg-shell clasp; d, mandible of 2nd instar larva; e, 3rd instar larva, diagram of tracheal system; f, 3rd instar larva before much rounding up—note egg-shell and larval exuviae on tail; g, 3rd instar larva with spiracular connections made with host's tracheae.

they are grouped symmetrically and longitudinally as soon as their great aggregate size renders the quarters cramped. I did not find any antennae; but no special study of sensorial organs was made. The integument is apparently naked. At no stage during the actual feeding life of the larva is it attached to the host-organs or body-wall.

First instar larva (fig. 1, *b*). Very delicate (collapses in Liquide de Faure). Colourless; wide cephalothorax, rounded anteriorly, tapering quickly to a long, narrow caudal portion. Usually the egg-shell remains clasping the end of the body like a glove (fig. 1, *c*) and remains in this position after ecdysis, so that finally the successive larval exuviae, more or less telescoped, may be found still fixed to the last larval skin, with the egg-shell at the apex of the curious appendage thus formed. The shape is much stouter, in proportion, just at hatching, the length being then 0.55 mm. only. Soon thereafter the larva becomes elongate. There is no coiling within the egg—the long caudal portion attenuates and lengthens later. Oral opening rather ventral, mandibles long, thin, simple, sharply-pointed and not essentially different from those of later instars, but considerably larger in proportion. The larva is apneustic, but there are two strong lateral tracheal trunks. Total length of example figured: 0.93 mm.

First instar larvae usually occur in 2nd or 3rd instar hosts, but may at times (C152) be found among *Carabunia* pupae ready to emerge, in 5th (?) instar hosts. This shows that oviposition may occasionally take place in nymphs of this age, already parasitised. Such young larvae are, of course, doomed.

Second instar larva (fig. 1, *d*). This is very like the first; the sickle-shaped mandibles, in fact, remain essentially the same right up to pupation. There is a complete tracheal system, with large lateral trunks, connected fore and aft, and bunches of fine tracheae, but so far as I could find no connection with the exterior.

Third instar larva (fig. 1, *f*). This is at first of the same general shape as the previous instars. There are ten distinct segments and a tail.

The tracheal system (fig. 1, *e*) is strongly developed, the tracheal trunks connected with spiracles and filled with air. The body is filled with very long, fine, hair-like tracheae, coming off in bunches from the lateral trunks and from the two commissures, but scarcely branching at all.

There is one pair of anterior spiracles and two of posterior ones. Of the latter, one lies between the last segment which precedes the tail and the penultimate. This pair receives a tracheal branch from the end of the lateral trunk where it joins the posterior commissure. The other pair opens between the penultimate and the antepenultimate body segments and receives a branch from the lateral trunk (see fig. 1, *e*). Length, 2.3 mm.

As development proceeds in this stadium the larva becomes shorter and broader, losing the tail, though still very pointed caudally. It is then only 2.09 mm. long (fig. 1, *g*).

Then, sometime before pupation, a very extraordinary thing happens, the mechanics of which I have been unable to elucidate. Very gradually, and one by one, the spiracles, of which we have seen there are three pairs (one anterior and two posterior) achieve a connection with some—apparently the nearest—of the host's abdominal tracheae. The attached spiracle becomes greatly sclerotised (fig. 1, *g*) and very much darkened in colour, and is apparently raised above the substratum. I could find no regularity in the tracheal attachments; nor is this to be wondered at when one considers the large number of larvae which may be crowded into one host-abdomen. The tracheae traced went chiefly to supply the intestine after leaving the parasite spiracles. That the connection with the host tracheae takes place very gradually is shown by the following series of conditions in four third instar larvae all in the same host:—

2 larvae entirely loose, with their own functional tracheal system.

1 with an anterior spiracle sclerotised and fastened to a host trachea. Tail and general shape still that of the early third stage.

1 with the shape of advanced third stage, and all the spiracles sclerotised and connected with host tracheae save the two posterior spiracles of one side.

There is no connection whatever between the spiracular trunks (and lateral trunks) and the sclerotised spiracles with their host-tracheal connections. Even the position of the sclerotised spiracle may not coincide with the end of the spiracular trunk which joined it before sclerotisation.

When one seeks to classify the larvae of *Carabunia* in the system suggested by Parker, in his great work (1924) on Chalcidoid larvae, many difficulties present themselves. *Carabunia* agrees most nearly with Parker's Group IV (p. 331). The segmentation is nearly similar and the naked integument also; but there are very fundamental differences, which really place *Carabunia* in a group by itself. Thus the respiratory system in Group IV is metapneustic, with a simple pair of open spiracles placed at the caudal extremity. *Carabunia*, as we have seen, possesses no fewer than three pairs of open spiracles. Again, the Group IV larvae are attached to the body-wall of the host by a sheath formed from the egg-shell. The egg-shell persists in *Carabunia* but there is no fastening to the body-wall of the host, nor to its organs.

7. The Pupa of *Carabunia*.

Pupation takes place within the partly sclerotised third larval integument, in the still unperforated abdomen of the active host. The anterior spiracles of this larval skin are situated just in the re-entrant angle between the head and pronotum of the pupa, dorso-laterally. The two hind parts touch the tarsus of the pupal hind legs just behind the wing-pads. Between these two levels, the larval integument is greatly darkened to a deep fuscous, and is probably indurated. Over the head and caudal portions, however, it is quite colourless and transparent.

The pupa itself, closely invested in this larval skin, later becomes wholly dark brown, and finally almost black.

There is at no time any connection whatsoever between the indurated larval spiracular areas, with their host-tracheal junctions, and the pupa. The complete larval skin with these outer affiliations may be peeled off, leaving the pupa naked.

Sometime before emergence of the imago, but not until the pupa is almost black, the space between the larval integument—this strange Hymenopterous *puparium*—becomes filled with gas (air?), giving a silvery appearance and causing the detached pupa to float at once to the surface of the dissecting water. Previously it had always sunk. The air coating is fairly generally distributed under the larval skin.

When the adult has emerged, air may still be found in the tracheae attached to the inside of the true pupal exuviae, showing that air, presumably that which fills the larval skin and is derived from the host tracheae, is taken in at the pupal spiracles.

Curiously enough, one but slightly advanced pupa, with, however, the head and legs of imago all indicated, was found in the usual larval skin, but with no connections between the spiracles of the latter and the host tracheae. Accompanying it in the host abdomen were four fairly dark pupae, attached in the usual manner described above.

One is greatly impressed with the arrangements which protect the pupa of *Carabunia* in the body of the host, and supply it with air. These are the more interesting in the light of Parker's discussion on page 350 of the above-mentioned work. He quotes Tothill's view that the sac which surrounds the larva of *Therion morio*, Fabr., in the body of its host, serves primarily as a protection against the attacks of phagocytes—the dangers of which are indicated by the strong tendency of parasites in general to avoid contact with the phagocytes *during pupation*.

Criticising this hypothesis, Parker instances the larvae of *Chalcis* and of *Pteromalus*, which live freely in the body of the host. "Elles ne possèdent point de sac mais ne s'en portent pas plus mal pour cela. Le sac n'est donc pas chez un parasite interne de la nymphe une nécessité absolue, et il n'est donc nullement certain que son rôle est de protéger la larve contre les attaques des phagocytes."

The major function of the puparium in *Carabunia* would seem to be in connection with the supply of air, but why such special arrangements should be necessary in *Carabunia*, but not in *Chalcis* or *Pteromalus* we do not know. Like Parker "nous sommes obligés de nous borner à constater. Nous ne pouvons pas expliquer."

Since the above was written, Dr. Thompson has kindly drawn my attention to an interesting paper by Miss A. L. Embleton (1904) on *Comys infelix*, an Encyrtid parasite of *Lecanium*. In this, as in *Carabunia*, the third larval instar achieves an intercommunication between the respiratory systems of the host and of the parasite. There are four functional spiracles instead of the six in *Carabunia*. "From each of these four spiracles there is a double tracheal tube running out into the host's body; these two branches become subdivided and ramify in the host-tissue, and by this means, it seems, the parasite obtains its air-supply. Whether these ramifying tracheae originate from the tracheal system of the Coccid host, or from that of the parasite for whose benefit we may presume they are functioning, is quite obscure. If the former be the correct interpretation, we must conclude that the host develops a respiratory system for the benefit of the parasite that is destroying it. If, on the other hand, the structures originate with the parasite itself, we have to deal with the remarkable fact that they constitute a tracheal system entirely outside of the creature to which they belong."

We have seen that in *Carabunia* these tracheae are unquestionably those of the host, and it seems probable that this is likewise the case in *Comys*. They still, however, in *Carabunia* at least, serve some of the host organs also, though their branching is modified.

In *Comys*, as the third instar larva passes into the prepupal stage, "the posterior pair of external tracheae become marked by the appearance of three red-brown plate-like structures on each side of the body of the larvae . . . ; they are situated at the point where the radiating external tracheae are united with the body-wall. These curious plates are present in the pupal condition, but are left behind when the pupal skin is cast These appear to be connected in some way with the respiratory function of the creature, for they are placed at the base of the large forked tracheal tube, which at that point effects its union with the body, or, in other words, branches out of the body at that point, to ramify over the membrane which encloses the insect Each of these curious plates is an oblong body applied closely to the outside wall of the abdomen It is not easy to determine what the function of these structures can be, but I suggest that they have some connection with respiration, seeing the radiating tracheae arise at the same place as these anomalous plates."

In *Carabunia*, as we have seen, the last larval skin (which is undoubtedly the enveloping membrane mentioned by Miss Embleton) becomes sclerotised especially round the functional spiracles, but special plates, applied to the outside wall, as in *Comys*, are not differentiated.

The pupa almost invariably occurs in a last instar nymph, though infrequently in a penultimate—but then usually only one in the host, showing that an unusual share of food (and space?) has perhaps accelerated development.

8. The Adult.

On emergence from the pupa, and from the host's abdomen, usually by a separate hole for each one, at least up to the first six, the adults eject small, clear, round

enamel-like spots of meconial matter. I saw some of these on a stem of *Hibiscus* in the Garden, within one centimetre of a spittle-mass still containing a nymph from which adult *Carabunia* had emerged. This was the only sign of the adults I have seen in the field. It is probable they are very short-lived, for in captivity, under the most favourable conditions, they never lasted more than 48 hours. Yet they were observed to feed a little on sultanas, and to drink from the host spittle-masses.

Emergence from the pupa takes place in the early morning, and the insects are active at once, crawling out of the spittle, running up the glass sides of the vessel, and cleaning themselves vigorously, or alighting right on a spittle-mass, to dash energetically over it, with never an entanglement. When weak and nearly dead (in second day of captivity) they are liable to become stuck to the spittle, but never while in their full vigour. While they are running their swollen hind-legs look disproportionately large.

These little wasps are somewhat, though not greatly, attracted towards light, but if they are to be manipulated by exploiting this urge, the light must be strong. A stronger tendency is to climb upwards, like ladybirds. They can jump a comparatively great distance when disturbed.

Oviposition is usually performed in 2nd instar nymphs, but eggs may be laid less frequently in later instars even up to the last. There is thus no special selection of unparasitised nymphs, even though these, in the later stadia, are easily distinguished by the unaided human eye. Eggs laid in already parasitised late instars are liable to die prematurely with the killing of the host by the emergence of the older parasites.

Females show an immediate and continued interest in spittle-masses, running all over them, tapping vigorously with the antennae. Smaller ones, containing nymphs of about the second instar they stab repeatedly with the ovipositor, the whole conical abdomen disappearing into the spittle. They were never observed to insert the instrument into first instar masses, though they palpated them frequently with the antennae.

A nymph oviposited in repeatedly (or at least stabbed with the ovipositor) on the morning of the 18th August, showed three very newly-hatched larvae when dissected at 2.30 p.m. next day, showing that the egg probably hatches in about a day.

During oviposition the long hair-like ovipositor is brought downward and forward and is released from the sheath apparently at the very outset.

All attempts to observe *Carabunia* ovipositing in the field were failures. In spite of constant watching of definite spittle-masses for periods varying from an hour to two and a half, at different times of the day, I never saw an adult *Carabunia* in the field.

9. Life-cycle.

Attempts to rear young parasitised nymphs through to the emergence of the adult *Carabunia* failed entirely. An investigator with more time at his disposal could probably do so by establishing the host-plants in pots or by making a sleeve which would permit observation.

Greatly swollen last instar nymphs brought into the laboratory usually produced *Carabunia* adults within two to three days.

The egg, in three cases under experiment, hatched in about a day.

How *Carabunia* spends the interval between broods of host nymphs is an entire mystery. The adults are apparently very short-lived. It would appear that the species is carried over in straggling nymphs; but these must be exceedingly rare.

Perhaps this is the chief limiting factor which prevents *Carabunia* from annihilating its host in spite of a rate of parasitism which is extraordinarily high.

In 1925 I suspected the possibility of a carry-over in frog hopper nymphs of other genera, with a different cycle, but the dissection of large series of nymphs of all the species I could find in the district seemed to negative this suggestion.

10. Technique.

Frog hoppers of the genus *Clastoptera* are apparently the hardest of all to rear. To do so by sleeving spittle-masses on the host-plant is easy, but to accomplish it under laboratory conditions is very difficult. In the corked tubes which the late E. A. Butler found so efficient for Heteroptera and the present writer for leafhoppers, *Clastoptera* nymphs seem unable to form spittle-masses, even though the plant remains in excellent condition, and such frog hoppers as *Tomaspis* (*Moncophora*) thrive. The best method found was to keep the foodplant in water and cover it with a lamp-chimney supported in the usual way. Here the nymphs formed spittle and grew to adults or yielded parasites. Young ones, however, did not long thrive even thus.

11. Summary.

1. *Carabunia myersi* is an extraordinarily efficient internal parasite of the nymphs of *Clastoptera undulata* and *Clastoptera* sp. in Cuba, and of a third species in the mountains of Haiti.

2. The rate of parasitism is from 65 to nearly 100 per cent.

3. The egg is laid in nymphs of about the second instar, the female wasp negotiating the covering spittle-mass with great ease.

4. There are three larval stadia, and pupation takes place within the indurated larval skin of the last larval instar, inside the abdomen of the still active host.

5. The spiracles of this Hymenopterous puparium achieve connections with certain of the abdominal tracheae of the host and by this means supply air to the pupa.

6. Dissection and experiment showed that *Carabunia* is not actually, nor is it likely to become, a parasite of frog hoppers of the genus *Tomaspis* (*Moncophora*) to which the Trinidad cane pest belongs.

I desire especially to thank my wife for assistance in every part of the investigation.

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NOTES ON ASIATIC CHALCIDOIDEA.

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From many parts of the world, but especially from South Asia and Africa, the Imperial Institute of Entomology receives an increasing number of Chalcidoidea, many being important as parasites of noxious insects, but mostly still very little known or even undescribed. The study of all these varied and often difficult species will be the work of many students on parasitic Hymenoptera. For our part we intend to publish a series of notes under the above title, alternatively with notes on African Chalcidoidea, as contributions to a knowledge of the most important or interesting species, the large majority of which have been bred.

In every case the types of new species are deposited in the British Museum.

Family PERILAMPIDAE.

***Perilampus microgastris*, sp. n.**

♀♂. Body quite black, without metallic shine. Antennae brown above, reddish below from the 5th or 6th joint; they may be also more or less reddish above or almost quite black; the scape and pedicel always black. Wings hyaline. Legs black, with some bluish or greenish shine on the middle and hind femora and tibiae; front tibiae yellow, except at base, middle and hind tibiae yellowish only at extreme tip; tarsi yellow. The male has the middle and hind tibiae brownish-black externally and broadly yellow at tip and internally.

♀. Head narrow, broader than the thorax; antennal furrow not deep, with the anterior ocellus placed in the upper end, the margins not carinated. Face flat, quite smooth, as also the frons and the cheeks; only the vertex transversely striate. Antennae inserted in the middle of the face, not reaching to the anterior ocellus; pedicel 1.5 times as long as broad; flagellum short, 0.7 of the length of the head; funicle with 7 joints, the first 2-3 subquadrate, the distal ones transverse; club small, not longer than the last two funicle joints together.

Thorax a little longer than broad; pronotum, mesonotum and scutellum strongly puncto-reticulated, the scapulae with a smooth and shining field along the parapsidal furrows. Axillae smooth, finely shagreened. Mesopleurae smooth and shining. Propodeon with a median carina, on each side of which is a rounded area bordered by carinae. Scutellum as long as the mesonotum, extending over the short vertical propodeon. Wings large, covered with whitish ciliae; costal cell broad; marginal vein very short, but still twice as long as the stigmal vein; postmarginal vein as long as the stigmal.

Abdomen smaller than the thorax, quite smooth; hind margin of the 2nd segment straight.

♂. Similar to the female. Antennae a little longer in proportion to the length of the face; abdomen smaller and less pointed behind; tibiae more yellowish.

Length: ♀ 1.7-3 mm., ♂ 1.5-2 mm.

INDIA: Hoshangabad, C.P., and Dehra Dun, U.P., 16 ♂♂, 23 ♀♀ (*S. N. Chatterjee*); Coimbatore, 2 ♀♀ (*Y. Ramachandra Rao*). MALAY PENINSULA: Serdang, 1 ♀ (*G. H. Corbett*). JAVA: Buitenzorg, 3 ♂♂, 9 ♀♀ (*R. W. Paine*).

Hosts. *Microgaster indicus*, Wilkn., *Apanteles machaeralis*, Wilkn., and a Braconid parasite of *Nephantis scrinopa*, Meyr. (India); larva of *Lamprosema diemenalis*, Guen. (Malaya); *Apanteles* sp., parasite of *Tirathaba* spp. (Java).

This species is very similar to the European *P. tristis*, Mayr, from which it differs by the smaller size, the absence of carinae running from the eyes between the ocelli, the scapulae being less broadly smooth, the reticulation on mesonotum and scutellum smaller, the marginal vein shorter and clearer, and the axillae less striate.

Family EUPELMIDAE.

Anastatus menzeli, sp. n.

♀. Aeneous-black with greenish shine, more violaceous on face, mesopleurae, end of scutellum and propodeon; the elevated hind margin of the mesonotum is shining green. A narrow longitudinal line on the pronotum and a broad transverse stripe at the end of the 1st tergite are white. Antennae brown above, reddish-yellow below, with the base of the scape and the club almost black, the latter more or less whitish below. Legs brown, the hind femora somewhat aeneous, the trochanters, tip of femora, base and tip of tibiae and tarsi reddish-yellow. Wings with a broad transverse cloud under the stigmal vein; nerves yellowish-brown.

Head finely shagreened, dull. Antennal furrow deep, with sharp margins, the superior margin straight, situated under the median ocellus. Ocelli forming a regular triangle, the lateral near the eye-margins. Eyes large, strongly convergent above. Antennae inserted on the sides of the face, near the cheeks; scape strong, a little thickened, shorter than the 5 following joints together; pedicel 2.5 times as long as broad; ring-joint small, quadrate or a little longer than broad; 1st funicle joint twice as long as the ring-joint but shorter than the pedicel; the following joints gradually shorter and broader, the 4th and 5th subquadrate, the 6th and 7th transverse; club with 3 joints, shorter than the 3 preceding joints together, truncate below.

Thorax shagreened, almost smooth, scutellum and axillae finely striate. Pronotum large, narrowed in front, the posterior half with parallel sides and with a transverse edge, on which are long ciliae. Mesonotum a little longer than broad, the deep parapsidal furrows meeting each other, before the hind margin, in a curve; between these furrows and the scutellum the mesonotum is raised and smooth. Scutellum rounded, with fine longitudinal striation. Propodeon short, with a median triangular area, the edges of which are sharp and raised behind; on each side of this area is a longitudinal furrow; spiracles oval. Mesopleurae finely striate, smooth in the middle. Wings large; marginal vein a little longer than the submarginal and 3 times as long as the stigmal. Legs with more or less thickened femora, the middle legs elongated, the spur of the tibiae a little shorter than the metatarsus; the first three joints of the middle tarsi with strong black spines.

Abdomen shagreened, dull, a little shorter and not broader than the thorax, strongly narrowed after the 5th segment; 1st segment a little longer than broad, the following segments transverse; the 2nd longer than the 3rd, the 3rd to 5th subequal in length, the last segments not much shorter; hypopygium prominent below, near the middle of the abdomen, the ovipositor reaching to the tip of the abdomen.

♂. Smaller than the female, the body more shining green, bluish on the sides and with some reddish shine; abdomen aeneous above, without white stripe; antennae brown with scape and pedicel yellow; legs entirely yellow, the coxae colorous with the body.

Length: ♀ 4.2-4.6 mm., ♂ 3.2-3.7 mm.

JAVA: Buitenzorg, 7 ♀♀, 4 ♂♂ (*R. Menzel*).

Host. Eggs of *Attacus atlas*, L.

Other specimens, bred from the same eggs, cannot be separated morphologically from this species, but differ very much in coloration. We distinguish them by the name :

Anastatus menzeli var. **obscurus**, nov.

♀. The body is darker, almost black, with some green, bluish or violaceous shine on the face, pronotum, hind part of mesonotum, end of scutellum and mesopleurae ; abdomen aeneous above, with a narrower white stripe on the 1st segment ; palpi black ; antennae quite black, only the club whitish below ; legs quite black, the femora somewhat aeneous, the knees alone yellowish. Wings with a broad brownish stripe under the stigmal vein and a second transverse stripe, narrower, under the base of the marginal vein. The antennal joints are a little longer, the first three funicle joints longer than broad.

One male is dark green with the abdomen aeneous ; 1st segment with a white stripe. Antennae brown with the scape greenish ; the ring-joint is a little shorter, transverse, and the funicle joints a little broader, the basal ones subquadrate, the last transverse. Legs brown, coxae and femora metallic dark-green ; knees and first two joints of the tarsi yellowish. Wings with only one transverse stripe.

JAVA : Buitenzorg, 5 ♀♀, 1 ♂ (R. Menzel).

Bred together with the type species.

This species differs from other *Anastatus* through the form of the abdomen which is not broader than the thorax, convex above from the 4th segment and rounded along the sides. The whole body is also more elongate, as is generally the case with *Anastatus*.

Two species described by Girault from Java, *A. locustae*, Gir., parasitic in eggs of Locustids, and *A. magniscapus*, Gir., without known host, are very different from our species.*

Another species, parasitic in the eggs of *Attacus atlas* and received from Malaya (G. H. Corbett), has been recognised to be *A. colemani*, Crawford.

Family PTEROMALIDAE.

Subfamily SPHEGIGASTERINAE.

Agiommatus attaci, sp. n.

♂. Body shining green ; occiput and anterior part of the pronotum bluish-black. Abdomen brownish-black, more or less greenish in the middle, violaceous at the base, the ♀ with two transverse yellow stripes, the 1st narrow on the 3rd segment, sometimes only faintly or not at all visible, the 2nd broader on the end of the 4th and the base of the 5th segments. The male has the abdomen blackish-violaceous, with a rounded whitish spot covering the 3rd and the base of the 4th segments. Antennae of ♀ brown, with scape, pedicel and anelli white ; of ♂ quite white or with the club brown. Tegulate and wing veins whitish. Legs entirely white in both sexes, only the anterior and posterior coxae are green like the thorax.

♀. Head large, broader than the thorax, finely reticulated ; seen from above it is transverse, narrowed behind the eyes ; seen from in front it is rounded, the eyes large, strongly converging above, so that the face is about twice as broad as the vertex. Clypeus broader than long, its anterior margin with two small teeth, between which it is incurved. Cheeks as broad as half the length of the eyes, finely transversely striate. Mandibles strong, each with 4 teeth. Ocelli large, the lateral situated near the eye margin, the anterior above the weak antennal furrow. Antennae

* Treubia, i, 1919, p. 5.

short, inserted in the middle of the face; scape short and narrow, not reaching to the anterior ocellus; pedicel about twice as long as broad; 3 ring-joints, the 1st very short, the two others a little longer, but all transverse; 1st funicle joint longer than the pedicel, about twice as long as broad; the following joints of the same breadth as the 1st but gradually shorter, the 2nd as long as the pedicel, the 5th slightly longer than broad; club with 3 joints, as long as two preceding joints together.

Thorax very short, little longer than broad, finely reticulated. Prothorax sharply carinated anteriorly; mesonotum much broader than long, with the parapsidal furrows weak and reaching only to the middle; scutellum large, longer than the mesonotum, strongly convex, more finely reticulated near the end than at the base; axillae finely shagreened, almost smooth; mesopleurae smooth, with an elongate rectangular area and punctate near its anterior margin. Propodeon almost smooth, with a median carina which is divided in the middle by a transverse carina; the carinae form together a cross and limit 4 areae, the 2 anterior areae a little larger than the 2 petiolar areae; spiracles elongate, oval, placed above lateral furrows. Wings large, broad; marginal vein not much shorter than the submarginal, about 2.5 times as long as the stigmal vein; postmarginal vein a little longer than the stigmal. Legs thin, hind tibiae with one short spur.

Abdomen petiolated, very small, not longer and much narrower than the thorax. Petiole narrow, twice as long as broad; 2nd segment as long as its hind margin; 3rd segment transverse, the hind margin angulated in the middle; the following segments shorter, with straight hind margins. Last segment very small; ovipositor hidden.

♂. Quite similar to the female. Antennae also with 3 ring-joints, the funicle joints a little narrower. Abdomen shorter, petiole twice as long as broad; 4th segment almost as long as the 2nd and 3rd together, posterior segments transverse.

Length: ♀ 3-3.5 mm., ♂ 2.5-3 mm.

MALAY PENINSULA: Kuala Lumpur, 39 ♀♀, 11 ♂♂ (*G. H. Corbett*). JAVA: Buitenzorg, 4 ♀, 1 ♂ (*R. Menzel*).

Host. Eggs of *Attacus atlas*, L.

The genus *Agiommatus*, Crawford,* is specially characterised, in our opinion, by the large head, with the eyes converging above, the small antennae with 3 ring-joints, and the propodeon with strong carinae forming a cross in the middle. Our species is closely related to *A. sumatraensis*, Crawf., but may be distinguished by the larger size, the brighter green of the thorax, the yellow transverse stripes on the abdomen and the green coloration of the coxae. *A. sumatraensis*, Crawf., was bred from the eggs of an unknown moth.

Trigonogastra brunneicornis, sp. n.

♀. Body dark green, almost black, especially on the head, with some bluish and violaceous shine on the thorax; abdomen dark aeneous-green, more or less brownish below, the petiole concolorous with the thorax. Antennae with scape, pedicel and ring-joints clear yellow, flagellum reddish-brown. Mandibles yellowish-brown. Legs entirely clear yellow, except the coxae dark green and the last joint of tarsi brown.

Head transverse, broader than the thorax, shining but very finely reticulated; vertex broad, ocelli in a low triangle, the lateral ocelli as far away from each other as from the eye margins. Seen from in front the head is rounded, a little broader than long, the eye margins parallel. Clypeus emarginate with 2 rather strong teeth in the middle. Mandibles each with 4 regular teeth. Antennae inserted in the

* Proc. U.S. Nat. Mus., xli, 1911, p. 278.

middle of the face; scape narrow and elongate, reaching to the anterior ocellus; pedicel short, not much longer than broad; the 2 ring-joints very small; 1st funicle joint distinctly longer than the pedicel, about twice as long as broad; the following joints gradually shorter, but all longer than broad, except the 6th which is subquadrate; club not broader than the funicle and almost as long as the 2 preceding joints together.

Thorax evenly reticulated, the reticulation smaller and stronger than on the head; pronotum with the upper edge acute; mesonotum with incomplete parapsidal furrows; propodeon shorter than the scutellum, with the same reticulation and without carinae. Wings large, reaching to the tip of the abdomen. Veins very pale, the marginal vein shorter than the submarginal, the postmarginal vein not much shorter than the marginal, the stigmal vein about 0.7 of the marginal, club small but distinct. Legs thin; hind tibiae with one spur.

Abdomen with a long and slender petiole, extending to the end of the trochanters; remaining part not longer than the thorax, broadest at the base of the 3rd segment, where it is narrower than the thorax, then gradually pointed behind; ovipositor slightly protruding.

Length: 2-2.3 mm.

CEYLON: Peradeniya, 3 ♀♀ (*J. C. Hutson*).

Host. Pupa of *Agromyza* sp., mining stems of *Hibiscus esculentus*.

Two other species, *T. rugosa* and *T. megacephala*, have been described by Waterston* from Ceylon. *T. brunneicornis* is very similar to the first of these species, a parasite of *Agromyza phaseoli*, but differs by the larger size, the darker green coloration of head and thorax, the presence of 4 teeth on both mandibles and the more elongated funicle joints. Another parasite of *Agromyza phaseoli*, *T. agromyzae*, Dodd,† is known from Australia.

Family ELASMIDAE.

***Elasmus corbetti*, sp. n.**

♀. Dark greenish, only the postscutellum yellow; abdomen aeneous, greenish at base, reddish below except at tip. Antennae brown, the scape yellow. Legs entirely clear yellow, only the upper half of the hind coxae dark, greenish above, and narrow brown stripes on the upper and lower margins of the middle and hind femora.

Head, seen from above, rounded in front, sharply carinated just behind the eyes. Ocelli forming a low triangle, the lateral ocelli as far distant from the eyes as from the median ocellus. Vertex shagreened, with few scattered punctures. Antennae with scape short, reaching to the middle of the face, pedicel narrow, about twice as long as broad, ring-joint small, transverse, the 3 funicle joints elongate, a little more than twice as long as broad, the 3rd somewhat shorter than the first two, club shorter than the two preceding joints together.

Thorax with the pronotum short, the mesonotum not longer than broad, the scutellum very finely shagreened, the postscutellum triangular, pointed and translucent at tip, the propodeon finely shagreened, shining. Wings elongate, reaching, at rest, to the tip of the abdomen; disk slightly infusate and densely covered with short ciliae except near the hind margin at base. Legs almost smooth, the hind tibiae with black ciliae arranged in regular lozenges.

Abdomen narrower than the thorax and longer than head and thorax together, pointed at apex; segments transverse, except the 1st and 6th which are longer than broad. Ovipositor slightly protruding.

* Bull. Ent. Res., v, 1915, p. 326.

† Trans. Proc. R. Soc. Australia, xli, 1917, p. 344.

Length : 2.2 mm.

MALAY PENINSULA : Kuang, 2 ♀♀ (*G. H. Corbett*).

Host. *Cnaphalocrocis medinalis*, Guen.

In our key to the Asiatic and African species,* this species runs down near *E. claripennis*, Cam. It may be distinguished by the quite dark abdomen above, without reddish stripes, by the shorter funicle joints and by the smoother head, on which the punctuation is more scattered; the thorax is also a little narrower and more shining green.

Family EULOPHIDAE.

Subfamily ELACHERTINAE.

Genus *Trichospilus*, nov.

Head transverse, very short behind the eyes; vertex with a sharp posterior edge. Eyes large, ciliate. Mandibles broad with 2 large and 5 smaller teeth; maxillary palpi 2-jointed, labial palpi with one joint. Antennae inserted near the clypeus, with 9 joints: small scape, pedicel, 2 ring-joints, 2 funicle-joints and 3-jointed club. Pronotum large; parapsidal furrows complete; scutellum without longitudinal furrows but finely longitudinally striate on the sides; postscutellum large; propodeon with a median carina. Wings with 2 tufts of black hairs, one below the submarginal vein, the other below the base of the marginal vein; submarginal and marginal veins of about the same length, stigmal vein one-fourth of the marginal, postmarginal vein almost undeveloped. Legs normal, somewhat broadened in the male; tarsi with 4 joints. Abdomen almost rounded, flat above, with a short petiole.

Through the form of antennae and thorax this genus is related to *Cirrospilus*, Westw., but may be distinguished at once by the short rounded abdomen and the two spots on each forewing formed by tufts of black hairs.

Trichospilus pupivora, sp. n.

♂♂. Body orange-yellow, frons sometimes with a faint violaceous shine; cheeks with a brown stripe extending from eye to mouth. Antennae yellow, pedicel and funicle more or less brownish. Legs quite yellow. Abdomen brownish-black, the petiolus yellow and the middle of the 2nd segment also more or less yellowish. The ♂ has the body entirely yellow, only the end of the abdomen brown. Wings hyaline, more or less smoky brown in the middle.

♀. Head quite smooth and shining. Ocelli close together, the lateral ocelli nearer to the anterior ocellus than to the eye margins. Cheeks as long as half the length of the eyes. Antennae short, the scape narrow, not reaching to the front ocellus, pedicel elongate, about 3 times as long as broad; the 2 ring-joints short and transverse; the 2 funicle joints subquadrate, the 1st a little longer than the 2nd; club elongate, much pointed at apex, longer than the funicle.

Thorax smooth, very finely reticulated on the mesonotum, with a few scattered long ciliae. Pronotum elongated into a neck, mesonotum with strong parapsidal furrows; scutellum truncate at apex, with a straight transverse furrow before the postscutellum, smooth in the middle, longitudinally densely striate on the sides; postscutellum broad in the middle, rounded behind; propodeon elongate, with a median carina and small lateral spiracular furrows, spiracles small and rounded. Wings large, the hairs forming the tufts much thicker than the other discal ciliation,

* Bull. Ent. Res., xx, 1929, p. 422.

which begins only below the 2nd tuft ; there are about 8 long hairs on the marginal vein, after which the marginal ciliae are small and weak. Submarginal vein not broken ; stigmal vein small, with a strong club ; postmarginal almost absent. Legs with the hind coxae large, strongly reticulated on the outer side ; hind femora only slightly broadened ; the 4 tarsal joints elongate ; middle tibial spur longer than the metatarsus.

Abdomen rounded, broader but much shorter than the thorax, smooth, very finely reticulated from the end of the 2nd segment ; petiole quadrate or a little longer than broad, shorter than the hind coxae ; 2nd segment the largest, reaching to the middle of the abdomen, the following segments transverse. Ovipositor not visible from above.

♂. Smaller than the ♀ ; antennae shorter, scape and pedicel broader, the 1st ring-joint very small, the 2nd not longer but much broader, almost as broad as the funicle joints ; the 2 funicle joints quadrate, club not much longer than the pedicel ; legs shorter and somewhat thicker, especially the femora, tarsi very short, the 3 first joints as long as broad.

Length : ♀ 1-1.2 mm., ♂ 0.9-1 mm.

INDIA : Coimbatore, 5 ♀♀ (*Ramachandra Rao*). CEYLON : Peradeniya, Lunuwila, Passara and Kurunegala, many specimens (*J. C. Hutson*). MALAY PENINSULA : Sepang, many specimens (*G. H. Corbett*). JAVA : Buitenzorg, many specimens (*R. W. Paine*).

Hosts. *Nephantis serinopa*, Meyr. (India) ; pupae of *Nephantis serinopa*, Meyr., *Thosea cervina*, Walk., *Spodoptera mauritia*, Boisd., puparia of Tachinid parasite of *Nacoleia annubilata*, Swinh. (Ceylon) ; *Tirathaba rufivena*, Walk. (Malaya) ; pupae of *Tirathaba* spp. (Java).

Subfamily ENTEDONINAE.

Euderus malayensis, sp. n.

♀♂. Body black, the female with dark greenish or aeneous and partly bluish shine. Antennae brown, the scape and the pedicel below yellow in the female. Legs black, coxae, especially the hind coxae, with bluish shine ; ♀ with the tip of anterior and middle tibiae and the hind tibiae almost entirely yellowish-brown, the tarsi white ; the legs of the ♂ are almost entirely black, only the tarsi whitish. Wings hyaline.

♀. Head shagreened, dull, the face only a little shining ; seen from above, the head is short, transverse, the eyes large, the lateral ocelli near the eye margins ; before the anterior ocellus is a transverse carina extending from one eye to the other. Antennae with 10 joints ; scape narrow, scarcely reaching to the anterior ocellus ; pedicel about twice as long as broad ; ring-joint very small ; funicle 4-jointed, the 1st longer than the pedicel, the 2nd shorter than the 1st, the 2 last a little shorter but still longer than broad ; club 3-jointed, about as long as two preceding joints together.

Thorax short, punctulate, the punctation smaller on the scutellum than on the mesonotum ; parapsidal furrows deep. The hind margin of the large scutellum extends over the postscutellum and partly over the propodeon ; this latter very short, transverse, smooth, with a median carina ; spiracles relatively large, rounded. Wings large and broadly rounded at tip ; marginal vein longer than the submarginal, slightly thickened at base, then gradually narrower to the end ; stigmal vein short, thin, club small ; postmarginal vein longer than the stigmal. Basal half of the wing without discal ciliae ; on the apical half they are mostly arranged in regular lines ; 3 lines come from the stigmal vein, the 1st forming a narrow radial cell, the 2nd curved, reaching to the tip of the wing, the 3rd directed to the base of the wing ;

the other lines are short, more or less parallel to each other and they all reach to the end of the wing; between these lines are a few scattered ciliae and 3-4 longer hairs are below the middle of the marginal vein. Legs relatively short, the hind coxae longer and stronger than the others.

Abdomen much narrower and about twice as long as the thorax, concave dorsally; segments elongate, the last longer than broad. Ovipositor protruding, as long as the last segment.

♂. Similar; antennae with the same number of joints, but the funicle joints shorter and covered with rather longer ciliae. Abdomen short, not much longer than the thorax.

Length: ♀ 2-2.5 mm.; ♂ 1-1.5 mm.

MALAY PENINSULA: Serdang, 5 ♀♀, 3 ♂♂ (G. H. Corbett); Kuala Lumpur, 3 ♀♀, 3 ♂♂ (H. T. Pagden).

Host. Larva of *Prays endocarpa*, Meyr.

The genus *Euderus*, Hal., is easily recognised among the ENTEDONINAE by the 10-jointed antennae with one ring-joint, the elongate abdomen and especially by the discal ciliation of the forewing being sparse and arranged more or less in lines; the presence of a few longer ciliae under the marginal vein is also characteristic.

We cannot find any difference between the genus *Euderus*, Hal., as defined here, and the genus *Secodella*, Gir., as described by Girault* and Crawford†. According to Girault,‡ who mentions three species of *Euderus* from the U.S.A., this genus has the "forewing with the line of long soft setae near and parallel to marginal vein as in *Secodella*" and is characterised by "the sparse and inconspicuous discal ciliation of the forewing;" it seems therefore that he distinguishes it from *Secodella* by the lack of rows of ciliae on the wings. But Schmiedeknecht (Genera Insectorum, 1909) mentions such rows of hairs in the description of *Euderus*, Hal., and the genotype, *Euderus amphis*, Walk., which is in the British Museum, has the discal ciliation partly arranged in rows exactly as in *Secodella* spp.

Secodella, Girault, must therefore be considered as a synonym of *Euderus*, Haliday, which is thus a widely distributed genus. *E. malayensis* is the first species known from South Asia.

* Arch. Naturg., lxxix. A6, 1913, p. 48.

† Proc. Ent. Soc. Wash., xvii, 1915, p. 142.

‡ Insectorum Insc. Menst., xii, 1924, p. 94.

SOME NEW INJURIOUS PHYTOPHAGA FROM SOMALILAND AND
UGANDA.

By G. E. BRYANT,
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Family HALTICIDAE.

***Sebaethe guavae*, sp. n.**

Blue-black, the basal joints of the antennae, coxae and base of the tibiae tinged with fulvous, the head greenish black, the prothorax and the elytra more metallic blue, finely punctured. Length, 4 mm.

Head greenish black, very feebly rugose, longitudinally carinate between the antennae; the antennae blue-black, clothed with short grey pubescence, extending almost to the middle of the elytra, the two basal joints tinged with fulvous, the

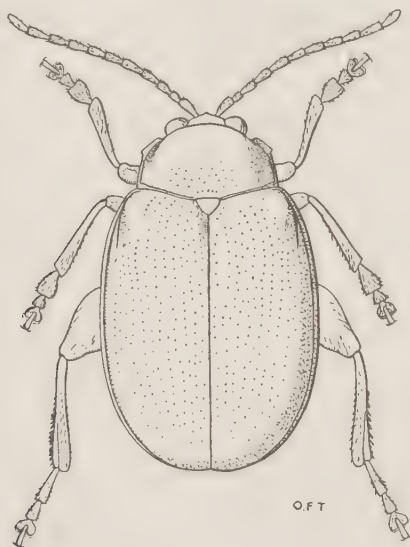


Fig. 1. *Sebaethe guavae*, sp. n.

first joint rather long, nearly twice as long as the second, and equal to the third, the third to the apical joint about equal. Prothorax transverse, metallic blue, somewhat convex, finely and irregularly punctured, the sides strongly margined, the anterior angles thickened and oblique. Scutellum triangular, metallic green, impunctate. Elytra metallic blue, more strongly punctured than the prothorax, the punctures almost forming striae, the sides almost parallel, but widest just before the middle, rounded at the base and the apex. Underside and legs blue-black, with the coxae and base of the tibiae fulvous, the tibiae clothed with long pale pubescence, the hind tarsi longer than the front and middle pairs, the ♂ with the first joint of the front and middle tarsi more swollen.

ITALIAN SOMALILAND: 2 ♂♂, 5 ♀♀, feeding on *Psidium*, viii.1926 (Prof. G. Paoli).

Allied to *S. vorax*, Wse., and *natalensis*, Jac., but differs in its colour being entirely blue.

***Epitrix pubipennis*, sp. n.**

Ovate, convex; black with the antennae and legs testaceous, the hind femora black, the front and middle pairs tinged with fuscous; the head black, glabrous; the prothorax strongly punctured with the interstices smooth, anterior angles prominent, the base with a strong transverse impression, the elytra punctate-striate, clothed with fine grey pubescence. Length, 2 mm.

Head black, glabrous; the antennae testaceous, extending almost to the middle of the elytra, the first two joints more swollen than the remainder. Prothorax black,

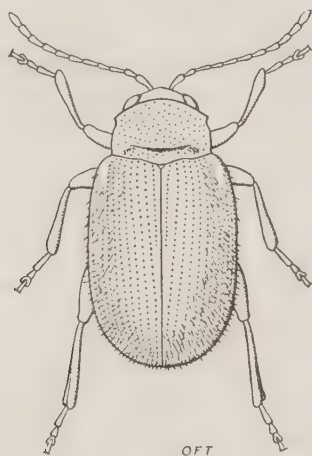


Fig. 2. *Epitrix pubipennis*, sp. n.

transverse, strongly punctured, with the interstices smooth, the sides almost straight and feebly margined, the anterior angles prominent, the base with a strong transverse impression. Scutellum black, very small. Elytra black, punctate-striate, clothed with fine grey pubescence. Legs testaceous, the hind femora black, the front and middle femora tinged with fuscous. Underside black and shining, the second, third and fourth ventral segments about equal.

UGANDA: Bugomolo, 6 specimens, feeding on *Solanum* sp., 24.iv.1927 (*H. Hargreaves*).

Allied to *E. laevifrons*, Wse., but may be distinguished by the black glabrous head, etc.,

***Phyllotreta hargreavesi*, sp. n.**

Oblong, subdepressed, nitid, obscurely blue-black; antennae with the second and third joints, and the base of the hind tibiae fuscous; head blue black, glabrous; prothorax and elytra blue-black and finely punctured. Length, 2 mm.

Head blue-black, glabrous; the antennae black with the second and third joints fuscous, extending to the middle of the elytra, the first joint about twice as long as the second, the remainder about equal to each other. Prothorax blue-black, very finely punctured, slightly transverse, the sides rounded and slightly contracted at the base. Scutellum blue-black, triangular, impunctate. Elytra blue-black, finely

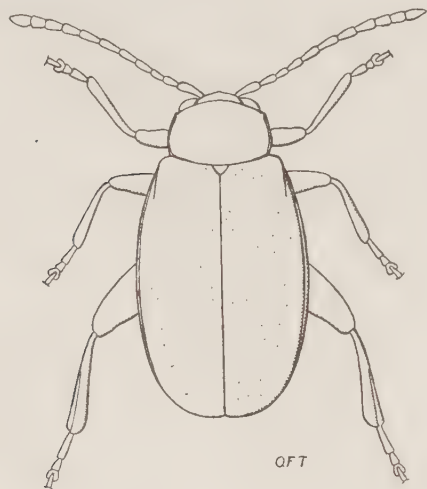


Fig. 3. *Phyllotreta hargreavesi*, sp. n.

punctured, slightly broader at the base than the prothorax, the sides parallel, and rounded at the apex. Legs and underside obscurely blue-black, impunctate, with the base of the hind tibiae fuscous, the ventral segments about equal.

UGANDA: Bukara Isle, attacking flowers of "Jobyo" (*Gynandropsis* sp.) 17.xii.1927 (*H. Hargreaves*).

May be placed in the *P. cruciferae* group, and near *P. flavilabris*, Wse., and *P. usambarica*, Wse.

DESCRIPTION AND BIONOMICS OF *FRANKLINIELLA INSULARIS* FRANKLIN (THYSANOPTERA).

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1. Introduction.
2. Systematic position of *Frankliniella insularis*.
3. Stages of the life-cycle.
4. Distribution and food-plants.
5. Seasonal prevalence.
6. Summary.

1. Introduction.

During the past two years Mr. G. Samuel, Plant Pathologist at the Waite Institute, and Mr. J. G. Bald, a member of the staff of the Division of Economic Botany of the Commonwealth Council for Scientific and Industrial Research, have been investigating spotted wilt of tomatos, a virus disease apparently peculiar to Australia and prevalent in the Adelaide district. They have studied the possible insect vectors of this disease and have shown that under experimental conditions it is readily transmitted by a thrips, *Frankliniella insularis* (Franklin), a species found on tomatos and other plants in the Adelaide area.* These investigators have published the results of their researches in Bulletin No. 44 of the Commonwealth Council for Scientific and Industrial Research. During the course of their experiments pure stocks of this species of thrips were reared in captivity, and although the insect was not specially studied from the entomological point of view, Mr. Bald, who was chiefly responsible for rearing the insects, accumulated a large amount of data bearing on its life-history. A technique for rearing the insect was evolved, based on the methods employed by Storey (Ann. Appl. Biology, xv, 1928, pp. 1-25) in his work with the leaf-hopper, *Cicadulina mbila*, a vector of streak disease of maize.†

During 1929 the present writers investigated certain aspects of the bionomics of *Frankliniella insularis* in more detail, and the observations are presented in this paper. Through the courtesy of Mr. Samuel many of the earlier observations referred to above as recorded by Mr. Bald have been incorporated in the paper.

* Specimens of this species of thrips were taken in carnation flowers and on tomato plants in the Adelaide area by G. Samuel in November and December 1927. The material was submitted to the Imperial Bureau of Entomology for determination, and the species was identified as *Frankliniella insularis* by G. D. Morrison, who stated that this was the first record for the species from Australia.

† The thrips were reared on leaves of tomato plants either in spring-clip tubes or in small glass lamp-globes. The spring-clip tubes were 9 mm. internal diameter and were supported on wire stakes by spring clips in a convenient position. One end of the tube rested on the leaf surface, the latter being pressed up to the mouth of the tube from below by a cork and rubber stopper attached to a spring; the other end of the tube was plugged with cottonwool. In this way the insects at various stages were restricted to the small area of leaf enclosed by the end of the tube; single individuals were readily isolated in this way. With the breeding globes, a leaf of a young tomato plant was inserted into the globe, the petiole being surrounded with a plug of cottonwool. The other end of the globe was plugged with cottonwool. The insects in various stages were reared on the leaf inside the globe. Complete details of this technique will be found in the Bulletin referred to above.

2. Systematic Position.

Frankliniella insularis belongs to the family THIRIPIDAE, Uzel, suborder Terebrantia, Haliday 1836, order Thysanoptera, Haliday 1836.

Franklin first described the species in 1908 (Proc. U.S. Nat. Mus., xxxiii, p. 715) and placed it in the genus *Euthrips*. This generic name had been used by several authors in the sense of *Physapus*, Karny 1907 (Berl. Ent. Zeits., lii, pp. 17-52). Franklin in 1908 (*loc. cit.*) pointed out that the name *Physapus* was already preoccupied by Leach in the Neuroptera. The generic name *Frankliniella* was used by Karny in 1910 (Mitt. Naturw. Ver. Wien, viii, p. 46) as a substitute for *Physapus*, Karny 1907.

Hood in 1914 (Proc. Ent. Soc. Washington, xiv, p. 34) states that the generic name *Euthrips* was originally used by Targioni-Tozzetti in 1881, but maintains that in the sense in which it was used by this author the name falls as a synonym of *Thrips*, Linn. 1758. The species *insularis* is listed in the genus *Frankliniella* by Karny in 1912 (Zool. Ann., iv, p. 334), and Hood in 1914 (*loc. cit.*) designated *Thrips intonsa*, Trybom 1911, as type of the genus.

The characters of the Australian specimens we have before us fit very well the generic characters of *Frankliniella* given by Priesner (Die Thysanopteren Europas, ii, 1926, p. 246), except that the comb-like formation of bristles on the posterior end of the 8th abdominal tergite is not developed. Franklin found this feature present in the specimens he collected in Barbados.

The generic characters evident in the Australian specimens are as follows:—Antennae 8-segmented; maxillary palpi 3-segmented; the bristles located along the veins of the anterior wings extend in an unbroken row along their length; the interocellar bristles are situated slightly in front of the posterior ocelli; the sides of the head may tend to narrow slightly proximally, but are not swollen as is the case in the genus *Parafrankliniella*; the long bristle situated on each antero-lateral angle of the prothorax is *distinctly* longer than the remaining bristles on the anterior border of the prothorax.

The following table which is adapted from Priesner (1926, *loc. cit.*) shows the distinguishing features for the three related genera *Kakothrips*, Williams 1914, *Frankliniella*, Karny 1910, and *Parafrankliniella*, Priesner 1920.

- (1) Interocellar bristles situated *between* the posterior ocelli; anterior tarsi armed at the end with small teeth; male with a chitinous horn on each side of 8th abdominal segment *Kakothrips*
- (2) Interocellar bristles normally situated immediately *in front of* the posterior ocelli; anterior tarsi not armed; no chitinous horns on 8th segment.
 - (a) Outer bristles on the antero-lateral angles of prothorax longer than the inner bristles situated along the anterior border of prothorax; a continuous row of bristles along the veins of anterior wings *Frankliniella*
 - (b) Outer bristles on the antero-lateral angles of prothorax shorter than the inner bristles situated along the anterior border; the row of bristles along the veins of anterior wings interrupted by small gaps *Parafrankliniella*

3. The Stages of the Life-cycle.

A. The Ovum.

The egg is whitish, ovate, shaped somewhat like a kidney bean, being ca. 0.7 mm. long by 0.3 mm. broad. On the tomato plant it is deposited in the tissues of the leaf, usually near a vein (fig. 1, *a*). The female inserts the egg into the tissues in a slanting position, and its anterior end can sometimes be seen through the open wound made by the ovipositor. When the larva hatches out it crawls directly on to the leaf surface. The eggs are readily demonstrated in the tissues of the leaf

by clearing the latter through alcohol to clove oil or xylol. A portion of a leaf treated in this manner is shown in fig. 1, *a*. The eggs are well advanced to the hatching stage and the eyes and segmentation of the embryos are clearly visible through the delicate chorion of the egg.

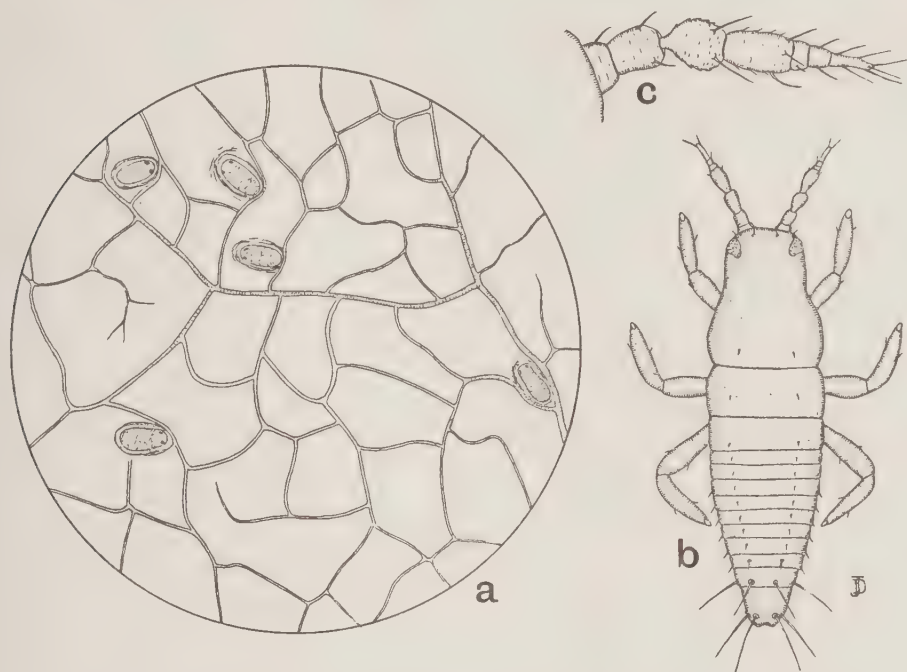


Fig. 1. *Frankliniella insularis*, Frank.: *a*, portion of leaf of tomato plant showing eggs in the tissues—the leaf fixed with alcohol and cleared through xylol; *b*, first stage larva, and *c*, antenna further enlarged.

Eggs have also been laid under glasshouse conditions in October and November in the tissues in the inside of the sepals of carnation flowers and also in the tissues of the petals. Females were found to lay readily in these situations in captivity in breeding globes. In a few cases the larvae hatching from these eggs were reared to maturity and found to be *Frankliniella insularis*.

(1) *Experiments on oviposition.*

In captivity in the glasshouse females oviposited at all periods of the year. Males were usually present in the colonies, but non-fertilised females which were isolated either as pupae or as newly emerged adults laid eggs which developed parthenogenetically.

During the winter of 1929 several individual females were isolated in spring-clip tubes on leaves of young tomato plants (see footnote on page 365). The females in every case were unfertilised, having been isolated either as pupae or as newly emerged adults. The eggs were laid in the tissues of the leaf area bounded by the mouth of the tubes. The tubes were moved to fresh areas of the leaf either daily, or in some cases after a varying period of days. The portions of the leaves on which the thrips

had been feeding were then cleared through alcohol to xylol, and the number of eggs present was counted. In this way the daily rate of oviposition was obtained.

Owing to the difficulties of the technique a few of the thrips died or were lost during transfer from one area of the leaf to another. Consecutive observations, however, were obtained from nine individual females and the results are shown in fig. 2. In the case of individuals A, B and C, the number of eggs laid daily was recorded. In the case of individuals D to I, the numbers were recorded at intervals

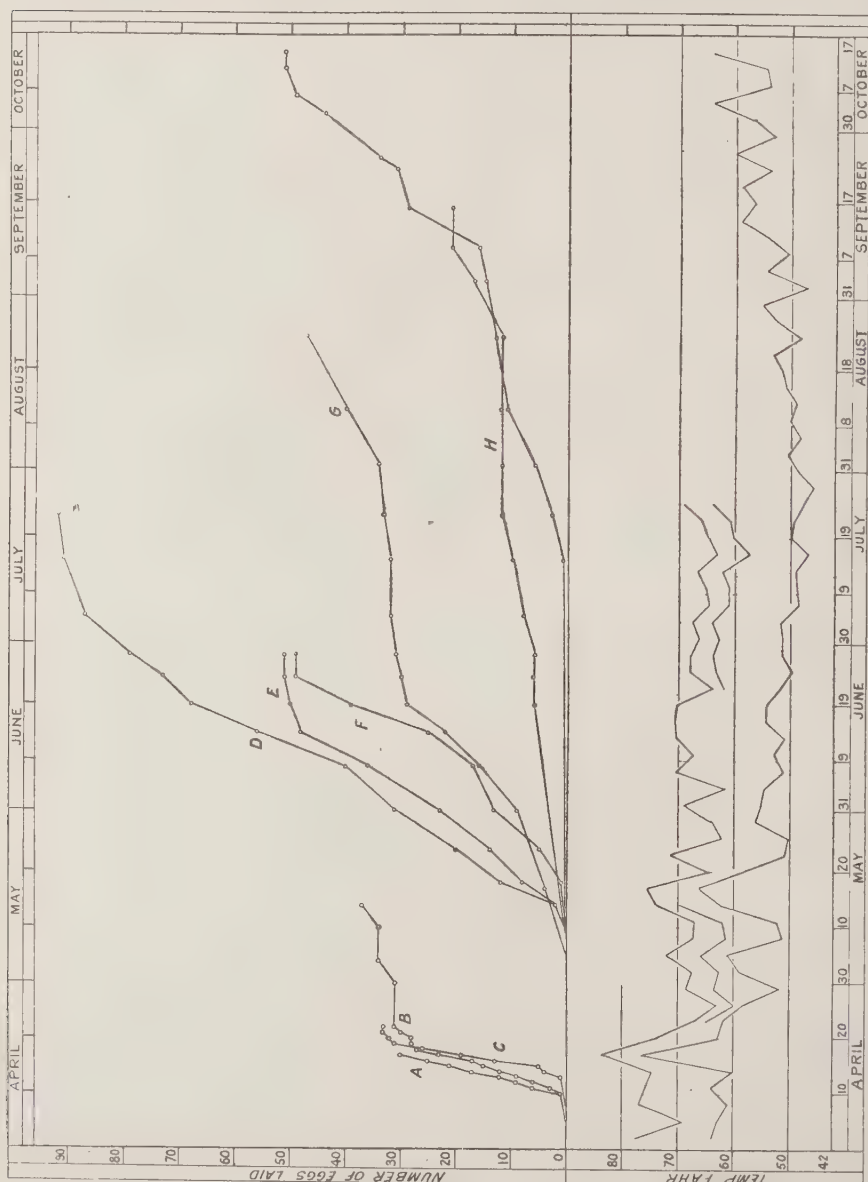


Fig. 2. Rate of oviposition of nine females (A-I) of *Frankliniella insularis* at various temperatures. The points on the curve show number of eggs laid up to the dates indicated (progressive totals). The top line temperature curve shows glasshouse temperatures (thermometer hanging 3 ft. above bench) expressed as the average mean daily temperature for 3-day periods. The lower line shows outside air temperatures. The middle line shows temperature for certain periods as recorded by thermograph on bench in glasshouse.

of a varying number of days. The points on the curves for each female show the dates the eggs were counted and the total number of eggs laid by the particular female at any selected date. The number of eggs having been plotted as progressive totals, the difference between the values of any two points on the curves gives the number of eggs laid during that period.

The females A to F were reared in the glasshouse, and the temperature during the egg-laying period is plotted as the average mean daily temperatures for three-day periods.* Females G, H and I were reared in the open in the shelter of a wooden box as a protection against the wind, rain and direct sunshine. The outside air temperature during the period is shown, being plotted as average mean daily temperatures for three-day periods.

It is clear from fig. 2 that the temperature obtaining after the adult female has emerged from the pupal sheath affects the length of time which elapses before oviposition commences. Females A, B and C began to oviposit five days after emergence, the average daily mean temperature for this period being 73.8° F. Females D and E began to oviposit five days after emergence, and F in nine days, the average daily mean temperature being 72.7° F. and 69.1° F.

Females G, H and I (under outside temperatures), on the other hand, began to oviposit after 12, 40 and 67 days respectively. With the exception of the period about 13th to 20th May, the temperatures were comparatively low. It is not clear why individual G should begin to oviposit much earlier than the other two females. It should be noted, however, that G emerged on 5th May, five days earlier than H and I. During this period the daily temperature was somewhat higher than later temperatures.

(2) *Rate of oviposition.*

The female A laid 30 eggs between 10th and 18th April, and then died, giving an average of 3.75 eggs daily. The mean temperature of the period was 75.4° F.

C laid 33 eggs between 10th and 22nd April, and then died, giving a daily average of 2.75 eggs. The mean temperature of the period was 77.1° F.

B laid 31 eggs between 13th and 22nd April, an average of 3.9 eggs daily. The mean temperature of this period was 77.5° F. After 22nd April the rate of egg-laying was slower, which coincides with the noticeable drop in temperature. This female was lost on 14th May, a total of 37 eggs having been laid.

With females D, E and F, the rate of egg-laying was slower in association with the lower temperatures. D and E laid 51 and 73 eggs respectively between 14th May and 24th June, a daily average of 1.2 and 1.7 eggs. The mean temperature of the period was 68.2° F. Individual D continued oviposition until 23rd July, when it died, having produced a total of 92 eggs in 70 days, being a daily average of 1.2 for the whole oviposition period. Individual F produced a total of 49 eggs between 18th May and 24th June, being a daily average of 1.3. The mean temperature of this period was 67.7° F.

* These temperatures were obtained from daily readings of a maximum and minimum thermometer hanging on the wall of the glasshouse 3 ft. above the bench. The records from a thermograph placed on the bench were found to give on an average a daily mean temperature about 5° F. lower than the maximum and minimum thermometer hanging above the bench. It is possible that the actual temperature experienced by the insects was somewhat lower than registered by this thermometer.

In fig. 2 the mean temperature is shown for two periods calculated from the thermograph records and plotted as average mean daily temperature for three-day periods. The temperatures referred to in the paper are taken from readings of max. and min. thermometer in the glasshouse except where stated otherwise.

With the females G, H and I the rate of oviposition was considerably slowed down in association with the lower temperatures. The rise in the curve in the case of female I about the second week in September is of interest, as it was evidently associated with the rise in the temperature curve.

Female D (see above) laid the greatest number of eggs recorded for a single female. The maximum number of eggs laid by a single female in one day was 8. In one instance a female laid 8, 6, 7, 5 eggs on four successive days, the mean daily temperature during these days ranging from 76.5 to 82° F.

A number of females were fed on leaves of tomato seedlings in spring-clip tubes for two days in April 1929, the mean daily temperature being 72.3° F. The number of eggs laid gave a daily average of two eggs per female.

(3) *Length of oviposition period.*

It is seen from fig. 2 that with mean temperatures below about 60° F., the oviposition period is very long. In the case of females G and H, for instance, which were not carried through to death, the periods were 111 and 130 days respectively. With female I the complete period was 157 days.

(4) *Duration of egg stage.*

Records regarding the duration of the egg stage were obtained as follows. On various dates in June 1928 single leaves were cut from a tomato plant grown in the glasshouse, and placed with their petioles in damp sand under small lamp-globes. Twenty mature females were placed in a globe, left to feed and oviposit for 24 hours, and then removed to fresh leaves in another globe. The leaves were kept under observation, and as the larvae hatched the latter were counted and removed. In this way records were obtained for 64 larvae. The data from these experiments are given in Table I. The results obtained are also shown graphically in fig. 6.

TABLE I.
Duration of Egg Stage of F. insularis.

Expt. Series.	Date in June 1928 when		No. of eggs hatched.	Duration of egg stage in days.	Av. M.T. of period ° F.
	eggs were laid.	larvae hatched.			
I	9	{ 18	1	9	64.3
		{ 20	1	11	64.6
		{ 21	3	12	64.3
		{ 22	8	13	64.8
		{ 23	1	14	64.6
II	11	{ 20	1	9	64.4
		{ 22	1	11	65
		{ 23	8	12	64.8
		{ 24	3	13	64.6
III	12	{ 24	4	12	64.4
		{ 25	4	13	64.8
IV	13	{ 25	2	12	64.9
		{ 26	11	13	64.8
		{ 27	2	14	64.8
V	14	{ 26	10	12	65.1
		{ 27	2	13	65
		{ 28	2	14	64.8

The variation in the average mean temperature for the different periods was practically negligible, the average mean for the 64 cases being 64.5° F.

An analysis of Table I shows that the number of days which elapsed from the laying of the eggs to the hatching of the larvae varied from 9 to 14.

2 larvae hatched after	9 days	=	3.1%
2 "	"	11 "	= 3.1%
27 "	"	12 "	= 42.2%
28 "	"	13 "	= 43.8%
5 "	"	14 "	= 7.8%

The average number of days for duration of the egg stage for the 64 cases was 12.5, with a mean temperature of 64.5° F.

It is of interest to note that out of 15 eggs laid on 13th and 14th of June (series IV and V), eleven and ten larvae respectively hatched on 26th June, which appears to be associated with the high mean temperature of 69° F. on 25th June, compared with the two previous days when it was 63.5° and 62° respectively (see fig. 6).

Further data relative to the duration of the egg stage were obtained from nineteen stock cultures of *Frankliniella insularis* during various periods in 1928 and 1929. In these cases the thrips were reared on young tomato plants in breeding globes. A variable number of mature adults was introduced into each globe and the first date on which newly hatched larvae were observed was recorded. The period between these two dates was taken as the duration of the egg stage. The results are given in Table IA.

TABLE IA.

Duration of Egg Stage of F. insularis at various periods during 1928-1929.

No. of globes recorded.	Egg stage in days.	Av. M.T. of periods ° F.
1	3	100
1	4	88.8
1	4	83.5
3	5	74.4
2	6	76
4	7	70.8
3	8	66
1	13	64.4
2	14	62.7
1	15	63.1

B. The Larval Stages.

(1) *First stage larva* (fig. 1, b, c).

The larva when newly hatched is about 0.45 mm. long and about 110 μ wide across the thorax; it is pale yellowish in colour with the body segments clearly defined; the abdominal segments bear a transverse row of four minute bristles, but the two terminal segments bear conspicuous bristles 44 to 60 μ long; antennae about 130 μ long, with seven visible segments having relative lengths 11, 22, 26, 37, 6, 8, 20.

(2) *Second stage larva* (fig. 3, a, b).

Orange-yellow in colour, length about 1.0 mm., width of thorax 0.2 mm.; a transverse row of four fine bristles on the dorsum of abdominal segments, and a few

bristles on thorax; the bristles on the two terminal segments of abdomen about 55μ long; antennae about 164μ long, seven segments visible, relative lengths being 13, 26, 35, 44, 7, 9, 26.

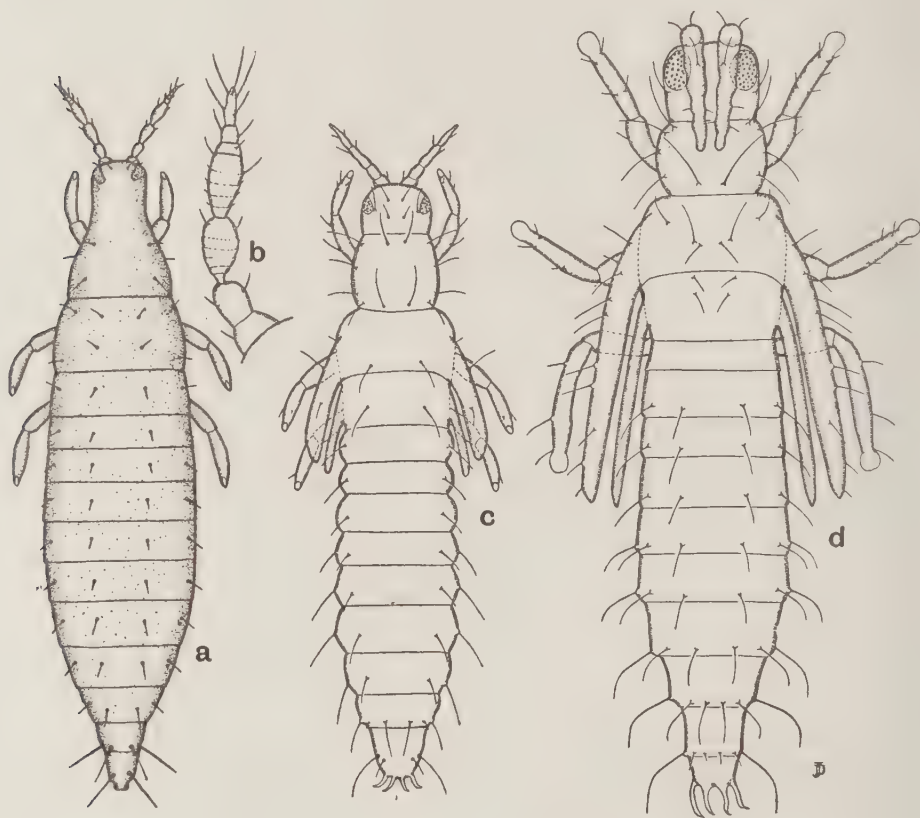


Fig. 3. *Frankliniella insularis*, Frank.: a, second stage larva, with b, its antenna further enlarged; c, prepupa; d, pupa.

(3) Duration of larval stages.

The duration of the larval period was obtained for 32 individuals during June and July 1928. The larvae were reared in spring-clip tubes on tomato leaves. They readily pupated in the cottonwool plugs.*

Details of these experiments are given in Table II, and the results are shown also in fig. 6.

* During the summer period larvae of *Frankliniella insularis* were found pupating in dried rolled leaves and in crevices between the calyx and the fruit on tomato plants in the open, so that the cottonwool plugs afforded a suitable medium. This latter habit has been observed by Russell in his investigations with *Heliothrips fasciatus*, Pergande (U.S. Dept. Agric. Bur. Entom. Bull. 118, Oct. 1912).

TABLE II.

Duration of Larval Stages of F. insularis.

Date on which larvae		No. of larvae pupated.	Duration of larval stage.	Av. M.T. of period.
hatched.	pupated.			
June 26	July 6	3	10	64.7
" 26	" 7	4	11	64.5
" 27	" 9	4	12	65.1
" 28	" 7	1	9	64.8
" 29	" 8	1	9	65.4
" 30	" 10	1	10	66.4
July 1	" 12	1	11	66.7
" 2	" 12	3	10	66.6
" 3	" 12	1	9	66.9
" 4	" 16	2	12	66.4
" 5	" 16	2	11	66.4
" 5	" 17	1	12	65.9
" 6	" 17	3	11	64.9
" 7	" 18	1	11	65.5
" 7	" 20	1	13	66.6
" 8	" 20	3	12	66.6

An analysis of Table II shows that the length of the larval stages varied as follows :

3 larvae	9 days with average M.T. of period	65.7° F.
7 "	10 "	" " " 65.9°
11 "	11 "	" " " 65.6°
10 "	12 "	" " " 66°
1 "	13 "	" " " 66.6°

The average duration of the larval period for the 32 individuals was 11 days with an average mean temperature of 65.9° F.

Further data relative to the length of the larval stages which are shown on Table IIa were obtained from the records of stock cultures in five breeding globes during 1928.

TABLE IIa.

Duration of Larval Stages of F. insularis in breeding globes during various periods in 1928.

Date newly hatched larvae recorded.	Date pupal stage recorded.	Larval period in days.	Av. M.T. of period ° F.
April 18	May 1	10	67.2
July 3	July 17	14	63.4
July 9	July 22	13	65
Sept. 12	Sept. 20	8	73
Oct. 30	Nov. 7	7	74.9

(4) *Habits of the larval stages.*

The young larva on hatching from the egg takes about 15 minutes to free itself and after resting a few minutes commences to feed. The effect of the feeding on the leaves of the tomato plant resembles that produced by the adults. The feeding

areas show up as whitish silvery spots. The larvae do not congregate in colonies, but may be found distributed over the plant. On carnation plants they were found only in fully expanded flowers, and usually in the flowers of other food-plants.

C. *Pupal Stages.*

There are two distinct pupal stages—prepupa and pupa. In the prepupa the wing-cases are much shorter than in the pupa, and the antennae are free and directed forwards, whereas in the pupa they are directed backwards over the head and thorax.

(1) *Prepupa* (fig. 3, c).

Colour orange-yellow; length about 1.0 mm.; body hairs long and fine, much longer than in larva; wing-cases reach to about abdominal segment III; antennae about 154μ long, the segments not clearly defined and bearing a few fine hairs; thorax with a long delicate bristle, about 55μ long, situated near each angle of the prothorax, and two lateral bristles slightly shorter; two or three delicate bristles on fore wing-case; long bristles on the abdominal segments, those extending over the lateral margins being about as long as the segments; the bristles near the end of abdomen about 66μ long; four stout curved spines at end of abdomen.

(2) *Pupa* (fig. 3, d).

Colour orange-yellow; length about 1.2 mm.; body bristles hyaline, conspicuously long and more numerous than in the prepupa; antennae enclosed in a sheath and directed back over the head, extending to about anterior third of the prothorax, bearing a few long delicate bristles; the bristles on antero-lateral angles of prothorax about 88μ long; wing-cases reach to about abdominal segment VI, and the fore-wing cases bear about eight long curved bristles; the bristles on the posterior abdominal segments distinctly curved and about 110μ long.

(3) *Duration of pupal stage.*

The duration of the pupal stage was obtained for 19 individuals reared in breeding tubes during July 1928. Details of these observations are summarised in Table III and the results are also shown in fig. 6.

TABLE III.
Duration of Pupal Stages.

Date in July 1928 when		Number of adults emerged.	Duration of pupal period in days.	Av. M.T. of period ° F.
larvae pupated.	adults emerged.			
6	19	1	13	66.7
7	19	1	12	66.7
7	20	1	13	67.1
8	20	1	12	69.1
9	20	1	11	69.1
9	21	2	12	69.8
9	23	1	14	70.3
10	24	1	14	70.2
11	24	1	13	70.3
12	23	5	11	71.5
16	25	1	9	70.3
17	24	1	7	72.4
18	27	1	9	72.8
21	30	1	9	71.5

An analysis of Table III shows that the duration of the pupal stages for the 19 individuals varied as follows:—

1	adult emerged in	7	days, average M.T.	72.4° F.
3	"	9	"	71.5° F.
6	"	11	"	70.3° F.
4	"	12	"	69.4° F.
3	"	13	"	68.0° F.
2	"	14	"	70.1° F.

The average duration of the pupal period for the 19 cases was 11.6 days, with an average M.T. of 70° F.

Additional records were obtained from stock cultures in four breeding globes during 1928, which gave the following number of days for the pupal period—15, 14, 9, 8—when the mean temperatures for the periods were 63.3, 67.5, 71.7, 73.4° F.

The range in duration of the pupal stages recorded above varied from 7 to 15 days. The figures shown in the analysis of Table III form a regular series except for the last two individuals. Notes made at the time of the experiments show that in these cases it was difficult to determine exactly when the individuals pupated.

(4) *Habits of the pupal stages.*

When the larvae are fully mature they seek a suitable place to pupate. Reared in captivity they pupated in the cotton-wool plugs in the spring-clip tubes and on the leaf or in the cottonwool plugs of the breeding globes. When reared on seedling tomato plants in pots covered with lamp-globes the larvae occasionally pupated on the plant, but usually in the loose pieces on the surface of the soil or in the soil itself at various depths to about 3 inches.

Pupae have been found in the field during the summer period in curled leaves of tomato plants, in depressions in the stem, under the calyx on the fruit, and in the space between two apposed fruits. Occasionally pupae have been found in carnation flowers. In general, however, the mature larvae leave the food-plant, and our observations and experimental results indicate that they pupate in débris on the surface of the ground, in crevices in the loose surface soil, and in the upper layers of the soil.

Search was made for pupae in the field in these places, but none was found, and washing the soil by means of the Morris apparatus (Bull. Ent. Res., xiii, 1922, p. 197) gave negative results. The search for pupae in their natural habitat, however, was not an extensive one.

A number of experiments were set up in 1929 to find out where the larvae pupated. Seedling tomato plants were grown in 4 inch and 6 inch pots, one plant in each pot. They were each infested with larvae, covered with a small lamp-globe which fitted close to the edge of the pot, the junction being sealed with plasticine. The top of the globe was covered with bolting silk. The plants were kept under daily observation, and in due course the larvae disappeared from the plant in order to pupate. Certain of the pots were kept until the adults had emerged. With others, the plant and surface of the soil was examined to see if any pupae were above soil-level, and then the soil was removed in convenient layers and washed through a fine sieve, pupae being sought in the residue.

The presence of vegetable matter in the soil made the search for pupae a difficult operation, and in the soil-washing experiments only an occasional pupa was found. With the pots which were retained for the pupae to complete development however,

adults emerged in due course, although the percentage of adults obtained compared with the number of larvae used in each experiment was low. In four examples the following results were obtained :—

Experiment 1. Ten larvae were placed on a seedling tomato plant on 27.iii.29. Two larvae pupated in the loose soil surface and the remainder descended into the soil. Six adults emerged from this pot.

Experiment 2. Fifteen larvae were placed on a plant in another pot on the same date. By 31st March no larvae or pupae were visible on the soil surface or on the plant. By 2nd May four adults only had emerged. The average mean daily temperature of the period was 65.8° F.

Experiment 3. Twenty-five larvae were used in another pot on the same date. By 1st April no larvae or pupae were visible on the plant or surface of the soil. By 27th April three adults only had emerged. The average mean daily temperature of the period was 72° F.

Experiment 4. Ten larvae were used in another pot on 15.vi.29. By 21st June one pupa was found on a leaf of the plant, two pupae on the stem of the plant, one pupa on the surface of the soil. By 5th July six adults had emerged. The average mean daily temperature of the period was 68° F.

Since it was definitely established that the larvae pupate in the soil, an attempt was made to find out how deep they go. In order to remove vegetable matter from the soil the latter was lightly washed in water before using it in the pots, and the floating debris was skimmed off. The soil was then air dried and mixed with 50 per cent. of sand. The seedling tomato plants were potted in this soil, tall glass beakers being used, the tops of which were covered with muslin. The depth of soil was four inches. The larvae were placed on the plant; when they had disappeared from the plant in order to pupate, the plant and surface of the soil were examined for pupae and then the soil was washed through a fine sieve in convenient layers.

The following four experiments illustrate the kind of results obtained :—

Experiment 1. Sixty larvae put on one plant on 1.xi.29. By 7th November they had pupated. Five pupae were found on the leaves and stem of the plant, five pupae in the loose surface soil in crevices of pieces of soil, five pupae in the first half inch depth, four pupae in the second inch depth, and two pupae in the soil below 2 inches deep. The mean temperature of the period was 67° F.

Experiments 2, 3, 4. Ten larvae on a single plant in each case on the same day gave : In experiment 2, one pupa on leaf petiole, one pupa in top half inch of soil, and one pupa below two inches deep. In experiment 3, no pupae found on plant, two pupae in the loose surface soil, and one pupa in the first half inch depth. In experiment 4, no pupae found on the plant, one pupa in the first half inch, and two pupae in the second half inch depth of the soil.

D. *The Female* (fig. 4).

Length, 1.3 mm. ; *width of mesothorax*, 0.25 mm. *Colour* deep brown to blackish brown ; thorax and abdomen somewhat lighter brown than head ; antennae with two proximal segments dark brown, middle segments lighter, grading into dirty brown on distal segments ; eyes dark brown faintly tinged with red ; ocelli brownish yellow with crescent area darker ; wings paler than body, fringe brown ; legs with coxae and femora brown ; tibiae lighter, especially fore tibiae ; tarsi yellowish

brown. *Head*, length 110μ , width 165μ , cheeks straight, faintly narrowing proximally, a transverse ridge on dorsal surface about one-fifth from posterior margin; *eyes* about 54μ antero-posteriorly and 22μ transversely; *ocelli* well separated; *ocellar bristles* 44μ , situated at anterior ends of posterior ocelli; *postocular bristles* about 34μ , two small bristles situated in front of anterior ocellus near median line, a small

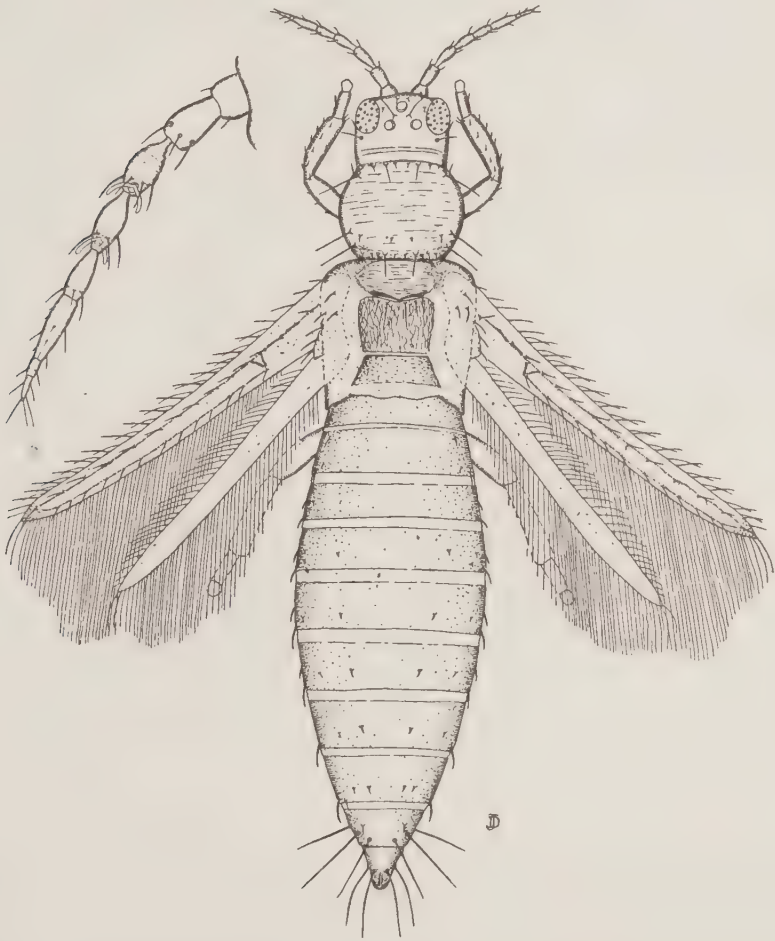


Fig. 4. *Frankliniella insularis*, Frank., adult female, with antenna further enlarged.

bristle on each side of anterior ocellus towards inner margin of eyes; on ventral side *mouth-cone* extends to coxa I, length from base of antennae to tip of mouth-cone about 208μ , two bristles on each side behind base of antennae, the pair nearer the median line being the longer, about 35μ ; a small bristle on each side near postero-internal margin of eyes; two bristles about 25μ on each side of median line near

posterior margin of head ; *antennae* about 0.26 mm. long, relative lengths of segments, 17.6, 33, 50.6, 44, 33, 50, 11, 17.6 ; segments bear prominent bristles about 26μ long, especially on distal part of segments ; forked sense-organ near distal end of segments III and IV.

Prothorax 143μ long, 220μ wide, sides rounded ; on *dorsum* a long bristle 66μ near each antero-lateral angle directed posteriorly, also a small one 13μ directed anteriorly ; six very small bristles forming a row along anterior border ; two long bristles about 70μ near each post-lateral angle ; two shorter bristles 38μ , one on



Fig. 5. *Frankliniella insularis*, Frank., adult male, with antenna further enlarged.

each side of median line near posterior border, and a row of about 12 small bristles along posterior border ; a few small bristles scattered over posterior area of pro-notum.

Pterothorax : *mesoscutum* with two short bristles near post-lateral angles, and one or two other short bristles along posterior margin ; *metascutum* I with four prominent bristles along anterior border, close together, the two nearer median line about 55μ long, and the other two 30μ ; on ventral side a row of three bristles extending along inner post-lateral border of mesothorax, and a conspicuous bristle near post-lateral angle of metathorax ; a few smaller bristles scattered over venter of pterothorax.

Wings reach to segment VII; anterior margin of fore wings bears about 20 stout bristles 66μ long interspersed with others not so stout; anterior vein bears about 17 and posterior vein about 14 short stout bristles. *Legs* bear rows of short stout bristles, two situated on inner face of each tibia at the distal end stouter than the remainder; the spines on inner face of tibiae or posterior legs stouter than on the others.

Abdomen: *pleural plates* connecting tergites and sternites are denticulate on posterior border, a stout spine at post-lateral angle of each segment, except segment I, also a spine about the middle of lateral margin of segments; bristles on segment IX, four conspicuous bristles on tergum, two outer bristles about 120μ , and two nearer median line about 103μ ; on segment X also four conspicuous bristles the pair nearer the median line about 126μ , and the outer pair about 116μ ; a few smaller bristles on each segment; on the venter *sternites* bear a prominent row of six bristles about 33μ long on posterior borders of segments II to VII; on segment IX two conspicuous stout lateral bristles about 88μ , and on segment X about 66μ ; a row of fine bristles on each side of median line over segments VIII to X.

E. *The Male* (fig. 5).

Smaller and narrower than the female; *length* about 1.0 mm., *width* of thorax 0.2 mm. *Colour*: general colour lighter than in female; on venter of abdominal segments III—VII a distinct sole-shaped, light-coloured area. *Head*, length 110μ , width 132μ ; *antennae* about 240μ , relative length of segments, 20, 33, 48, 39, 33, 44, 9, 13. *Wings* reach to abdominal segment VII. *Abdomen*, on segment IX two long bristles each about 72μ , two near median line quite short, 9μ , and two on post-lateral angles each 66μ ; on segment X two bristles on post-lateral angles each 66μ ; on venter of segment IX, two lateral bristles each 44μ , and two on post-lateral angles as in the other segments; on segment X one bristle at each post-lateral angle each 66μ long.

F. *Duration of the Complete Life-Cycle*.

An idea of the duration of the complete life-cycle under experimental conditions in the glasshouse is obtained from the previous tables dealing with the duration of the various stages of the insect, and from fig. 6. The examples given, however, except in seven cases, deal with different individuals selected at different stages. These seven individuals, which were reared in breeding tubes, were carried through from the egg to the emergence of the adult. The results obtained are given in Table IV.

TABLE IV.

Duration of complete Life-cycle of F. insularis.

No.	Date 1928.		Duration of various stages in days.			Total days.	M.T. of period ° F.
	Eggs laid.	Adults emerged.	Egg.	Larva.	Pupa.		
1	June 13	July 19	13	10	13	36	65
2	"	"	13	11	12	36	65
3	"	July 20	13	11	14	38	66
4	"	"	14	12	11	37	66
5	"	July 21	14	12	12	38	66.9
6	June 14	"	13	12	12	37	66.6
7	"	July 23	13	12	14	39	66.8

The duration of the period from the hatching of the larvae to the emergence of adults was obtained for 19 individuals reared in breeding tubes during June and July 1928. The periods varied from 18 to 24 days. The average mean temperature of the different periods varied from 65.6° F. to 69.7° F.

Records of observations made on 36 stock colonies reared on tomato plants under breeding globes during various period in 1928 and 1929 show the length of the

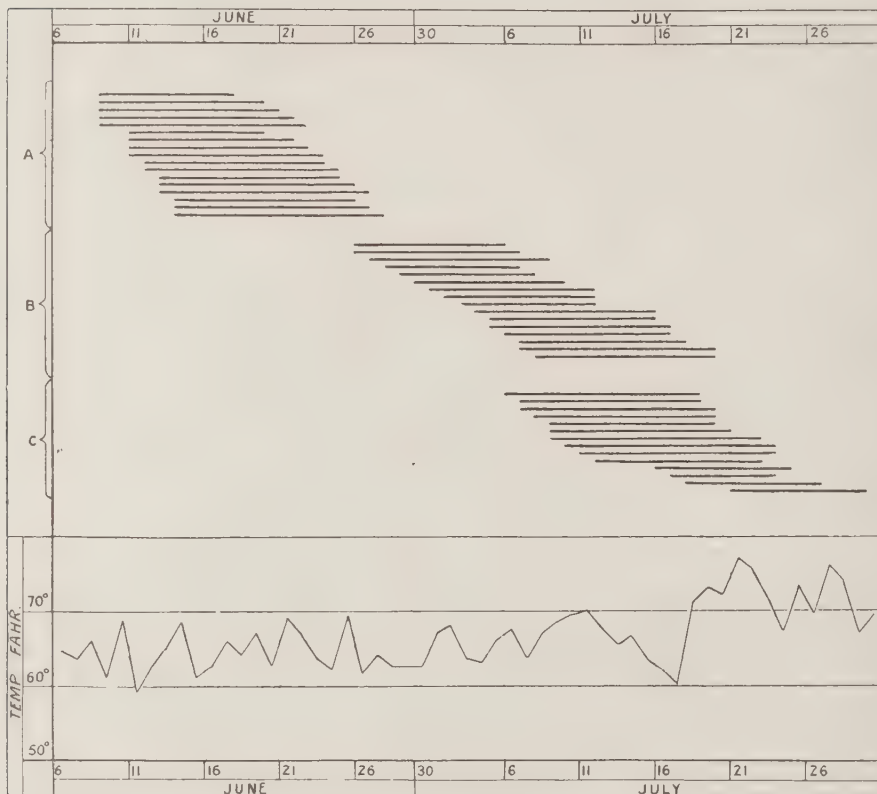


Fig. 6. Length of (A) egg stage, (B) larval stages, and (C) pupal stages, of *Frankliniella insularis* in relation to temperature. Each of the horizontal black lines represents the length of period obtained from one or more individuals commencing on the date indicated by the beginning of the line. With the exception of seven individuals which were carried through from the egg stage to emergence of the adults, different individuals were used in the various stages. The mean daily temperature in the glasshouse as recorded from a maximum and minimum thermometer is shown below.

complete life-cycle under different mean temperatures. In establishing these stock colonies, a number of mature adults were introduced into each globe, and the duration of the life-cycle was calculated as from this date to the date on which adults of the next generation were observed. As the individuals were mature and many were used in each case, it is highly probable that eggs were laid within 24 hours after they were

placed on the plant. Observations were not made on consecutive days after the adult thrips were introduced, so that in some cases the recorded date of the emergence of adults of the next generation may be one or two days later than their actual emergence. The data obtained, however, represent a close approximation to the duration of the life-cycle under the conditions stated. The results are summarised in Table IVa.

TABLE IVa.

Duration of complete Life-cycle of F. insularis in breeding globes.

Month eggs laid.				No. of globes observed.	Life-cycle in days.	Av. M.T. of period ° F.
April 1928	...	...	...	2	28	69.9
				1	28	71.1
May	...	...	...	2	28	69.5
				1	33	68
				1	35	68
				1	39	67.8
June	...	...	...	7	38-45 (Av. 41.4)	64.1
July	...	...	...	1	27	71.4
				1	27	73.0
August	...	...	...	1	21	75.5
				2	22	73.9
				1	23	73.8
				1	26	73
				1	26	72.6
September	...	...	...	1	24	72.8
				1	24	73.6
				1	26	72.8
				1	26	69.3
October	...	...	...	1	21	72.2
				1	23	74
				1	23	74.6
				1	24	74
February 1929	...	...	...	1	13	89.5
April	...	...	...	1	23	72.2
				1	25	72.8
October	...	...	...	1	19	79.8
				1	20	79

It is seen from Tables IV and IVa that the duration of the complete life-cycle varied from a minimum of 13 days, when the average mean temperature was 89.5° F., to a maximum of 45 days, when the average mean temperature was 64.1° F.

The different periods having the same mean temperature (to the nearest degree) as shown in the last two columns of Tables IV and IVa have been averaged. The sixteen points so obtained have been plotted in fig. 7, duration of life-cycle in days in relation to average mean temperature. The distribution of these points suggests the usual type of hyperbolic curve for development in relation to temperature.

When the reciprocals of these values are plotted the points are found to be distributed about a straight line which cuts the base line at 53°F^*

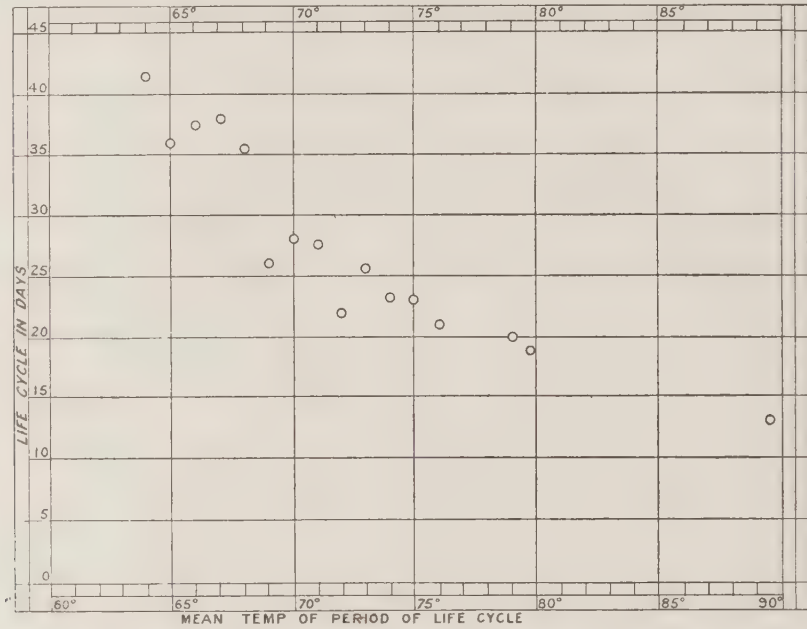


Fig. 7. Life cycle of *Frankliniella insularis*, complete development in days in relation to temperature. The sixteen points have been obtained from data given in Tables IV and IVa, as explained in the text.

4. Distribution and Food-plants.

The species *F. insularis* was first recorded by Franklin from Barbados and St. Vincent Islands. This author lists eighteen species of food-plants consisting of beans, roses, potatoes, tobacco, etc. Russell (Proc. Ent. Soc. Washington, xiv, 1912, p. 128) records it from Brownsville, Texas; Hood (Insec. Inscit. Mens., i, 1913, 149) from Porto Rico, collected by Dr. C. W. Hooker in blossoms of *Agati grandiflora* and orange trees. Hood states that it is an abundant species in southernmost Texas, and in all Central America, in at least the northern portions of South America, and on many, if not all, of the islands of the Caribbean Sea. Messrs. G. E. Bodkin and L. D. Cleare took it at Georgetown, British Guiana (see Proc. Ent. Soc. Washington, xvi, p. 29). Hood (Psyche, xx, 1913, p. 119) mentions that the species has been recorded from Guadalajara, Mexico (Crawford); Monterey, Mexico; Miraflores, Canal Zone, Panama. He states that it is probably the most abundant thrips in Central America. Pierce & Morrill (Proc. Ent. Soc. Washington, xvi, 1914, p. 21) took it in flowers of wild cotton (*Thurberia*) in Arizona. G. E. Bodkin (1915, Rept. Dept. Sci. Agric. British Guiana) collected it in British Guiana on flowers of *Couroupita guyanensis* (cannon-ball tree), and later (1916) recorded it from blossoms of various

* This would mean that the critical cold point for the species is about $53^{\circ}\text{F}.$, which seems high. If the actual temperatures experienced by the insects were $5^{\circ}\text{F}.$ lower than recorded, as explained on page 369, a shift of 5° to the left would place the critical cold point at about $48^{\circ}\text{F}.$

plants, including roses. P. G. Cardin (Mem. Soc. Cubana Nat. Hist., Havana, iii, 1918, nos. 2 & 3) refers to the species as injurious to the flowers of citrus in Cuba. C. B. Williams (Bull. Dept. Agric. Trinidad and Tobago, xvii, 1918) records it as occurring chiefly on flowers of Leguminosae, being numerous on *Erythrina glauca*, and states that it occurs throughout Central America and the West Indies on lima beans (*Phaseolus* sp.). J. R. Watson & E. Osborne (Florida Buggist, ii, 1919, no. 4) record it in Florida from flowers of Citrus and *Carissa grandiflora*. J. R. Watson (Florida Agric. Expt. Sta. Bull. 162, 1922) refers to the species having been found at Miami on *Carica* by A. C. Mason in 1918, who refers to it as the Cuban citrus thrips. L. A. Catoni (Rev. Agric. Puerto Rico, ix, 1922, no. 3) records it from Puerto Rico on sweet potato. L. Ogilvie (Rept. Dept. Agric., Bermuda, 1925) records it as attacking both flowers and leaves of beans (presumably *Phaseolus* sp.), and in his 1928 report refers to the species as a very common pest of lily blooms.

The species was first taken in Australia by Mr. G. Samuel from carnation flowers, and tomato plants in the Waite Institute grounds, November 1927. Since that time it has been collected from more than forty different food-plants in South Australia as follows:—

(a) *Adelaide district*: Ageratum, Agapanthus, Bignonia, Cichorium, Lonicera, Valeriana, Delphinium, Geranium, Jacaranda, Larkspur, Melon, Pansy, Stock, Verbena, Phaseolus, Malva parviflora, Oxalis cernua, Roses, Jasmine, Sweet Peas.

(b) *Mount Lofty*: Coreopsis, Cornflower, Cosmos, Foxglove, Gladiolus, Oleander, Poppy, Zinnia.

(c) *Macclesfield*: Antirrhinum, Fuchsia, Hollyhock, Lucerne, Opuntia, Petunia, Potato, Strawberry, Ulex.

(d) *Beetaloo Valley*: Cucumber, Trombone.

In addition to these records it has been taken in New South Wales, near Sydney, on Dahlia, and at Baulkham Hills on Canna and Sunflower. Also in West Australia, near Perth, on Easter Lily, and in Victoria, at Bendigo, on Antirrhinum and Tomato.

In general the insect inhabits the flowers of its food-plant, but in the case of the tomato plant it occurs also on the leaves and fruit. The species has not been found in sufficient numbers on tomato plants to constitute a pest of that crop. Counts made from time to time on tomato plants grown in the open showed that the insect was usually in quite small numbers (about one to five individuals to a plant, and often less). It was unusual to find as many as twenty individuals on a plant. It was only occasionally found on tomato plants grown in winter in commercial glass-houses. In certain garden flowers, particularly carnations, the number of individuals was much greater. During the hotter periods of the summer 1928-29 sometimes 20 to 30 individuals could be obtained from a single carnation flower.

5. Seasonal Prevalence.

General observations were made on the prevalence of the species on plants in the grounds of the Waite Institute during 1928 and 1929, particularly on an experimental block of tomato plants. No systematic method was adopted for recording the number of individuals, but the records made show clearly that the numbers begin to decrease about May, and only occasional individuals were recorded in June, July, August and September. Towards the end of September and early October the species was found more readily and gradually increased in numbers throughout the summer, being collected freely during December, January, February and March. From April onwards the numbers decreased.

The average mean daily temperatures for the different months in 1928 and 1929, taken from the Waite Institute air temperature records, are shown below :

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1928 ...	69.1	68.8	68.7	68.5	55.5	52.1	52.2	54.7	57.4	56.6	64.9	70.3
1929 ...	69.1	76.4	66.8	62.0	56.9	52.3	48.6	50.9	54.9	58.3	62.3	64.0

From the general trend of the curve in fig. 7 it is clear that under glasshouse conditions with mean temperatures below about 62° F., the developmental period for the life-cycle of the insect becomes rapidly extended and the mean monthly temperatures given for May to October explain the scarcity of *Frankliniella insularis* during these months in the Adelaide district.

The decreased activity of the insect at the lower temperatures is seen by the oviposition rate shown in fig. 2. The insects in the breeding globes were found to be quite sluggish, although they lived for long periods. It seems probable that the occurrence of adults occasionally found on plants in the open during the winter months is due to individuals which have emerged from hibernation owing to temporary favourable temperatures, or adults which have survived in sheltered situations. Larvae were not found during the period June to September. Two adults were found in a commercial glasshouse on a tomato plant in June 1929 and a few eggs had been laid in the leaves near the feeding marks.

As the insects have been readily reared in the glasshouse at all periods of the year, the factor which limits its distribution and multiplication in the open is evidently temperature.

6. Summary.

(1) *Frankliniella insularis* (Franklin) is found on various food-plants, including tomatoes, in the Adelaide area.

(2) The life-history and bionomics of the species have been investigated, particularly on tomato plants under glasshouse conditions. The various stages of the insect have been described.

(3) The eggs are laid in the tissues of the tomato leaf, and the larvae feed on the leaves or in the flowers ; when mature they leave the plants and pupate in the débris on the surface of the soil or penetrate into the upper layers of the soil. Sometimes they pupate on the plant in rolled leaves, depressions in the stem or other similar situations ; this habit has been also observed on tomato plants growing in the open during the summer. In carnation flowers eggs were laid in the tissues of the sepals and petals.

(4) The duration of the egg stage for 64 examples varied from 9–14 days when the mean daily temperature was 64.5° F. In a number of other observations it was found to vary from 3 days, when the mean temperature was 100° F., to 15 days, when the mean temperature was 63.1° F. The rate of oviposition is markedly affected by temperature : with a mean temperature of 77.5° F., one female laid an average of 3.9 eggs daily ; two other females laid an average of 1.2 and 1.7 eggs daily when the mean temperature was 68.2° F. ; and another female laid an average of 1.3 eggs when the mean temperature was 67.7° F. Below 60° F. the rate of oviposition is greatly retarded, but egg-laying may extend over a long period : one female continued oviposition over a period of 157 days. The largest number of eggs laid by a single female was 92 over a period of 70 days.

(5) The duration of the larval stages for 32 individuals varied from 9 to 13 days when the mean temperature of the periods varied from 66.6° F. to 65.7° F. In a

number of observations on other individuals at various times the period varied from 7 to 14 days when the mean temperature varied from 74.9° F. to 63.4° F.

(6) The duration of the pupal stages obtained from 19 individuals varied from 7 to 14 days when the mean temperature of the periods varied from 72.8° F. to 66.7° F.

(7) The complete life-cycle under glasshouse conditions occupied 36-39 days when the mean temperature of the period was about 66° F. Observations made on a number of individuals at various periods gave a variation in the period of the complete life-cycle from 13 to 41 days with mean temperatures varying from 89.5° F. to 64.1° F.

(8) The chief distribution of *Frankliniella insularis* appears to be the region of Central America. It is common in the Adelaide area during the warmer period of the year (approximately November to April), and rare or absent during the remaining months. Its seasonal occurrence appears to be due to temperature, since it was readily reared at all periods of the year on tomato plants in the glasshouse.

(9) The economic importance of the species is due to the fact that G. Samuel and J. G. Bald have shown experimentally that it can transmit the virus of spotted wilt disease of tomatos.

OBSERVATIONS ON THE PARASITES OF THE PINE-SHOOT MOTH,
RHYACIONIA BUOLIANA, SCHIFF.*

By W. H. THORPE, M.A., Ph.D.,
Imperial Institute of Entomology.

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2. List of Parasites reared.
3. List of other Species previously recorded from *R. buoliana*.
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6. Relative Importance of the Species.
7. Shipment to Canada.
8. Summary.

1. Introduction.

The Pine-shoot Moth, *Rhyacionia (Evetria) buoliana*, Schiff. (TORTRICIDAE) has long been known as one of the most injurious forest insects in Europe. It occurs throughout North and Central Europe and is confined to the genus *Pinus*. It is most frequently recorded from *P. sylvestris*, probably because this is the most important forest tree, but it also readily attacks *P. laricio* var. *austriaca*, *P. montana* var. *mughus*, *P. strobus*, and *P. resinosa*.

The damage caused is due to the habit that the young larva has of feeding and wintering in the interior of the developing buds, thus killing the shoot. Since young trees, up to about fifteen years of age, are the most frequently attacked, and since it is the terminal shoots which are, as a rule, infested, the damage caused in certain seasons is very serious and results in permanent malformation of the tree.

By reason of its mode of hibernation and its preference for young trees, it is a pest which is very easily transferred from one country to another on nursery seedlings, and in this manner it has no doubt been introduced into the United States on many different occasions. In 1914 it was reported to be doing serious damage on Long Island, and Busck (1915) writing the following year records it from nine States, reaching as far west as Illinois and Ohio, all these infestations having apparently been established during the years 1913-1915. Attempts at eradication were adopted too late to be successful, and in 1926 Heinrich regarded it as permanently established, although he stated that it was chiefly confined to nurseries and private estates and had not yet spread into the forests or large plantations of native pines.

In the same year a widespread outbreak was reported in Canada, the insect apparently having been introduced on young pines imported from Holland. At this time it was found in five localities in Ontario, as well as in Victoria, British Columbia.

In 1927 the Imperial Institute of Entomology, at the request of the Dominion Entomologist, undertook to make an investigation of the parasites of the moth in this country with a view to attempting the control of the Canadian outbreaks by biological means. Although the insect is by no means kept in complete control by parasites in Europe, yet since a number of parasites were already known to attack it in this country, it was felt that introduction into Canada of one or two of the more important forms without their natural hyperparasites might result in checking the spread of the pest in that country.

* Contributions from the Farnham House Laboratory, Imperial Institute of Entomology, No. 11.

A big infestation was reported in the spring of 1928 in the young plantations of the Forestry Commission near Brandon, Suffolk, and Swaffham, Norfolk, and work was begun by Dr. J. G. Myers and Dr. W. R. Thompson. It was soon found that the material from this district was well parasitised and arrangements were made for collections on a large scale. With the permission of the Forestry Commission, employees in the district were detailed to the work, and in the course of about a couple of weeks approximately 100,000 infested shoots were gathered and despatched to Farnham House Laboratory. Careful preliminary studies of this material were made with the help of Messrs. G. M. Spooner and A. H. Wood of Cambridge University. Samples of each batch of material were placed in incubators and the emergence of the parasites thus hastened. Numerous dissections were made and specimens of the later stage larvae of commoner species fixed and preserved for further study. As adults emerged they were pinned, together with, in a large number of cases, the cocoons from which they had emerged. Since these cocoons contained the cast skins of the last larval instar it was possible to obtain by their means accurate identification of the larval stages.

Mr. A. H. Wood also very kindly sent a number of specimens of parasites reared from *R. buoliana* in the New Forest in 1929. Eight species are represented in this material, the relative proportions being very close to those obtained from the Suffolk localities. One species, *Microbracon discoideus*, Wesm., was new to our list, no specimens having been obtained in Suffolk.

When the writer joined the staff at Farnham House Laboratory a very large quantity of valuable parasite material had accumulated, and, since there is no immediate prospect of being able to continue the work, he undertook, at the request of Dr. W. R. Thompson, to write a brief account of the more interesting results already obtained. This paper is accordingly little more than a summary of some aspects of the work. Further study of this large complex of parasites attached to *R. buoliana* would be certain to reveal other interesting facts, particularly as regards alternative hosts and the inter-relations of some of the forms. No attempt has been made to describe each stage of the larvae of the various species in full. The general structure and superficial appearance of the larval types characteristic of the main groups of ICHNEUMONIDAE are already well known. The structure of the head of the mature larvae has, however, been adequately described in very few species and consequently this phase has been investigated thoroughly with a view to the discovery of satisfactory specific and generic characters. The figures, unless otherwise indicated, show the head as it appears after treating in potash and mounting, without staining, in Faure's Fluid. It is hoped that they will render identification from adult larvae or from cast larval skins comparatively easy.

Dr. C. Ferrière has examined a considerable portion of the material, and the greater part of the identifications are due to him. His expert knowledge of the classification of the ICHNEUMONIDAE has been of the utmost value.

The late Mr. C. C. Brooks, of the Imperial Forestry Institute, Oxford, at the time of his tragic death in July 1930 was engaged in a further study of *R. buoliana* and the inter-relations of some of its parasites. Just as this paper was going to press Dr. R. N. Chrystal very kindly placed at my disposal the whole of Brooks' notes and material concerning the parasites with permission to make use of them in any way I desired. Unfortunately, the greater part was not in a sufficiently advanced state to allow of utilisation. I have, however, referred to Brooks' observations in one or two instances, the source of the information being indicated in the text in each case. The main part of the MS. which deals with the biology and economic importance of the moth itself is in a more finished condition and will be published by Dr. Chrystal in due course, together with a very brief summary of the section dealing with parasites.

2. List of Parasites reared.

ICHNEUMONOIDEA.

ICHNEUMONIDAE.

Ichneumoninae.

* *Phaeogenes coryphaeus*, Wesm. (?).

* *P. mysticus*, Wesm. (?). ♂.

Cryptinae.

* *Hemiteles bicolorinus*, Grav.

* *H. palpator*, Grav. (?). ♂.

H. spp.

* † *Gelis fallax*, Först.

Pimplinae.

Pimpla ruficollis, Grav.

* *P. robusta*, Morl.

P. brevicornis, Grav.

* † *P. elegans*, Woldst.

P. detrita, Holmg. (?).

P. examiner, F.

Lissonota transversa, Bridg.

* *Clistopyga incitator*, F.

Tryphoninae.

* † *Hypsantyx impressus*, Grav. (?).

Ophioninae.

Cremastus interruptor, Grav.

* *Eulimneria rufifemur*, Thoms.

* *Omorgus mutabilis*, Holmg.

* *O. borealis*, Zett.

* *O. ensator*, Grav.

BRACONIDAE.

* † *Microbracon abscissor*, Nees.

M. discoideus, Wesm.

* *Apanteles falcatus*, Nees.

Orgilus obscurator, Nees.

* *Eubudizon extensor*, L.

CHALCIDOIDEA.

PTEROMALIDAE.

* *Habroclytus acutigena*, Thoms.

* † *Eutelus mediterraneus*, Mayr.

TRICHOGRAMMIDAE.

Trichogramma evanescens, Westw.

DIPTERA.

TACHINIDAE.

Actia nudibasis, Stein.

* Not previously recorded from *R. buoliana*.

† Not previously known in Great Britain.

3. List of other Species previously recorded from *R. buoliana*.

ICHNEUMONOIDEA.

ICHNEUMONIDAE.

Ichneumoninae.

Ichneumon (*Cratichneumon*) *fugitivus*, Grav.

Pimplinae.

Pimpla turionellae, L.

P. buoliana, Htg.

P. alternans, Grav.

P. inquisitor, Scop.

P. (Scambus) sagax, Htg.

Glypta resinanae, Htg.

Lissonota humerella, Thoms.

Lampronota melancholica, Grav. (?).

Exetastes cinctipes, Ratz.

Tryphoninae.

Triclistus (*Exochus*) *curvator*, F.

Ophioninae.

Cremastus decoratus, Grav. (= *C. buolianus*, Curt.)

[*C. facilis*, Cress. Canada.]

Eulimneria albida (Gmel.)

Eulimneria crassifemur, Thoms.

Eulimneria geniculata, Grav.

Omorgus ramidulus, Brisch.

O. difformis, Gmel.

Angitia chrysosticta, Gmel.

Pristomerus vulnerator, Panz.

BRACONIDAE.

Chelonus sulcatus, Jur.

CHALCIDOIDEA.

PERILAMPIDAE.

Perilampus laevifrons, Dalm.

[*P. batavus*, Sm. v. Bur.]*

ENCYRTIDAE.

Copidosoma geniculatum, Dalm.

PTEROMALIDAE.

Habritys brevicornis, Ratz.

DIPTERA.

TACHINIDAE.

Actia crassicornis, Mg.

Leskia aurea, Fall.

Exorista (*Phryxe*) *vulgaris*, Fall.

4. Notes on the Structure and Biology of the more important Species.

Cremastus interruptor, Grav.

This striking black and yellow species was the dominant Ophionine obtained and was indeed one of the most frequent of all the ICHNEUMONIDAE present. It was

* No description of this species appears to have been published, it is therefore *nomen nudum*.

equally common in the New Forest. The members of the tribe CREMASTIDES are characterised by the broad stigma and radial cell, which latter is short, and this character serves to separate *Cremastus* from any other Ophionine genus recorded from *R. buoliana*. The distinction of *C. interruptor* from closely allied species is, however, a more difficult matter. There seems little doubt, as Morley holds, that *C. confluens*, Grav., is a synonym, for there seems no clear line of distinction between the two; the most important difference is said to lie in the more coarsely punctured mesopleurae of *confluens* coupled with the more generally darker coloration and the black hind legs, but in the material we have reared, every gradation and combination of the two characteristics is found to occur. It is said to be distinguishable from *C. decoratus*, Grav. (*C. buolianae*, Curt.) by the smaller size (9 mm. length) and more delicate build, and by thoracic colour differences. Although *decoratus* has been recorded from *buoliana* both in this country and on the Continent, we have reared no specimens which agree exactly with the descriptions of this species. Size and colour are very variable, and the structural differences given by Morley in his keys do not agree with those given in the text of the book. Since there are no specimens of *decoratus* in the British Museum I have not been able to go into the question, but it seems probable that even if *decoratus* is a good species, the records from *buoliana* may all refer to *interruptor*.

The insect is primarily an internal parasite of the larva. The larva usually emerges from its host in the latter part of June, or in July, and spins a cocoon of brownish silk. Emergence of the adults took place from 30th June till the 21st August, but the insect also fairly commonly delays its emergence till the host has changed to a pupa and the majority of the later emerging specimens came from *buoliana* pupae.

The first stage larva is of the caudate type already well known as typical of various groups of endoparasitic ICHNEUMONIDAE. It is cylindrical, without spines or appendages, and consists of a heavily chitinated head, thirteen body segments, and a long tapering tail, the whole measuring 3.5 mm. In general structure it is essentially similar to the larva of *Eulimneria crassifemur*, Thoms., which has been fully described by Thompson & Parker (1930); consequently a detailed account is not required here.

The general plan of the mouth-parts and tentorial structures of the mature larva has been described under section 5 (p. 403), where definitions are given of the terms employed. It will be seen from the illustrations that *C. interruptor* (fig. 6, a) can be readily distinguished from the *Omorgus* species and from *Eulimneria* by the slender labial struts and by the slender "labial ring" coupled with the wide upper ends. The long slender maxillary struts are also diagnostic, and the unique character of the large 'labral' sensillae should be noted.

Both sexes were abundant, the males constituting 62 per cent. of the total.

The species is recorded from throughout North and Central Europe although usually regarded as somewhat of a rarity.

Its recorded hosts are as follows:—

- | | |
|--------------|--|
| TINEIDAE. | <i>Gelechia (Exoteleia) dodecella</i> , L. |
| | <i>Hyponomeuta euonymellus</i> , L. (= <i>padi</i> , Zell. ?). |
| | <i>Nothris verbascella</i> , Hübn. |
| | <i>Scythris variella</i> , Steph. |
| TORTRICIDAE. | <i>Phalonia zephyrana</i> , Treits. |
| | <i>P. atricapitana</i> , Steph. |

Omorgus mutabilis, Holmg.

The large tribe CAMPOPLEGIDÆ, to which this genus belongs, can be differentiated by the long narrow stigma and radial cell. *Omorgus* can be distinguished from the other Campoplegine genera recorded from *buoliana* by the oblique and geniculate nervellus. In the species under discussion there is a considerable variation in the petiolar area of the metathorax, this being especially noticeable in the earlier hatched specimens and when a large series is examined; in a few cases it is flat, in others distinctly excavate, a characteristic of the genus *Limnerium* (sens. lat.), but the straight and more or less vertical nervellus and the absence of posterior constriction of the head of the latter are more reliable characters.

The following key, based on those of Schmiedeknecht and Morley, shows the diagnostic characters of the species of *Omorgus* with which we are concerned below.

- | | | | |
|---|------|---|------------------|
| 1 | (7). | Abdomen, at least of female, dorsally black throughout. | |
| 2 | (6). | Ventral plica infusate, petiolar area of metathorax generally sub-excavate. | |
| 3 | (4). | Metathorax sub-rugose and frequently distinctly excavate; length 5-7 mm. | <i>mutabilis</i> |
| 4 | (5). | Metathorax smoother and not deeply excavate; hind legs and tibiae pale | <i>difformis</i> |
| 5 | (4). | Hind femora basally and tibiae apically dark | <i>ramidulus</i> |
| 6 | (2). | Ventral plica stramineous, metathorax not excavate; hind femora black, trochanterellus and centre of hind tibia very pale yellow; length 4-5 mm. ... | <i>borealis</i> |
| 7 | (1). | Abdomen with segments 3-7 laterally red; legs red, with coxae and both extremities of hind femora black, centre of hind tibiae yellowish white, length 5 mm. | <i>ensator</i> |

O. mutabilis, which has not previously been recorded from *buoliana*, was found to be a fairly common species in Suffolk, occurring much the most frequently of the three. It was absent from the New Forest material. It is apparently double-brooded and is the earliest of all the important parasites of *buoliana* to emerge, having been present in the field at the time the first collections were made on 6th June. Emergence continued, with a slight lull at about the end of June, till 8th August. In the records of the earlier hatchings females were somewhat in excess, but later in the season the sexes were present in approximately equal numbers. The insect is an internal parasite of the larva, but the second brood is also frequently found emerging from the pupa. Although the host is single-brooded this second brood of parasites is rendered possible by the length of time over which *R. buoliana* emerges.*

The illustrations of the larval mouth-parts (figs. 4, c; 7, d) will suffice to distinguish *Omorgus* at a glance from the Pimplines and from *Cremastus*. There is, however, no single reliable larval character by which the genus *Eulimneria* can be differentiated from *Omorgus*, differences between them being of the same kind as those which characterise the species. Taken together, the shape of the arms and the degree of pigmentation of the open labial ring, coupled with the size and shape of the mandibular and maxillary struts provide satisfactory means for distinguishing *E. rufifemur* from *O. mutabilis*, the only species of the three with which it is likely to be confused.

* Brooks (M.S.) states that in the Forest of Dean the spring brood attacks *Tortrix viridana*, L., and *Cheimatobia brumata*, L., from neither of which has it previously been recorded.

O. mutabilis is of general European distribution and has been recorded from a large number of hosts, viz. :—

PIERIDAE.	<i>Pieris brassicae</i> , L.
NOCTUIDAE.	<i>Earias chlorana</i> , L.
GEOMETRIDAE.	<i>Eupithecia pimpinellata</i> , Hübn.
PSYCHIDAE.	<i>Proutia betulina</i> , Zell.
PYRALIDAE.	<i>Phlyctaenia sambucalis</i> , Schiff.
TORTRICIDAE.	<i>Clysia ambiguella</i> , Hübn.
	<i>Cnephasia virgaureana</i> , Treits.
	<i>Endothenia gentiana</i> , Hübn.
	<i>E. nigricostana</i> , Haw.
	<i>Eucosma ramella</i> , L.
	<i>E. pflugiana</i> , Haw.
	<i>Notocelia uddmanniana</i> , L.
	<i>Tortrix rosana</i> , L.

Omorgus borealis, Zett.

The chief diagnostic characters of this and the following species have already been given. It is a fairly common internal larval parasite emerging between 9th June and 8th July and was present in Suffolk and in the New Forest. It has been recorded as passing the winter as a larva in *Aristotelia stipella*, Hübn., and there is little doubt that it behaves in the same way as a parasite of *R. buoliana*. Morley's records also suggest that it may hibernate as an adult. It is double-brooded, and, as it is not a pupal parasite, very probably requires an alternative host. *A. stipella*, which is a common double-brooded insect feeding on *Chenopodium* and *Atriplex*, probably serves in this respect. No other species given in the list below appears to be suitable for the purpose in this country. The differences in the degree of chitination and shape of the labial ring, and in the shape of the mandibles and struts, taken together provide good larval specific characteristics (fig. 3, a).

Of the insects reared 69 per cent. were females.

O. borealis is known throughout North and Central Europe. It does not appear to have been recorded previously from *R. buoliana*, although the following hosts are known :—

PSYCHIDAE.	<i>Apterona helix</i> , Sieb.
	<i>A. crenulella</i> , Brd.
TINEIDAE.	<i>Aristotelia stipella</i> , Hübn.
	<i>Cataplectica auromaculata</i> , Frey.
	<i>Tischeria complanella</i> , Hübn.
TORTRICIDAE.	<i>Coleophora atriplicis</i> , Durr. (<i>maeniaceella</i> , Stt.).
	<i>C. pyrrhulipennella</i> , Zell.
	<i>C. troglodytella</i> , Dup.
	<i>Evetria sylvestrana</i> , Curt.

Omorgus ensator, Gray.

A rather uncommon internal larval parasite, twelve specimens having been reared between 21st June and 9th July; of these, ten were females. It occasionally emerges from the pupa. It has not previously been recorded from *R. buoliana*, and this insect is clearly one of its less important hosts. It is found on the wing

throughout the summer and has been recorded as wintering in *Argyroploce dimidiana*, Sod., as a larva (Morley). It occurs throughout North and Central Europe on the following hosts :—

- NYMPHALIDAE. *Vanessa atalanta*, L.
 NOCTUIDAE. *Eublemma rosea*, Hübn.
 Agrotis porphyrea, Schiff.
 PSYCHIDAE. *Luffia lapidella*, Goeze.
 AGERIIDAE. *Aegeria tipuliformis*, Clerck.
 TINEIDAE. *Coleophoraonosmella*, Brahm.
 Hyponomeuta plumbellus, Schiff.
 Lampronia quadripunctella, Steph.
 Phthorimaea instabilella, Dougl.
 P. salicorniae, Hering.
 Scythris grandipennis, Haw.
 Telphusa notatella, Hübn.
 T. proximella, Hübn.
 TORTRICIDAE. *Ancylis lactana*, F.
 Argyroploce bifasciana, Haw.
 A. dimidiana, Sod.
 Grapholitha ocellana, F.
 Gypsonoma minutana, Hübn.

Eulimneria rufifemur, Thoms.

The chief characteristics by which *Eulimneria* can be distinguished from *Omorgus* have already been mentioned. *E. rufifemur*, which is 4–5 mm. long, is separable from the somewhat larger *E. crassifemur* by the more slender and entirely red hind femora.* *E. albidum* also has red hind femora, but the lateral petiolar sulci are fine and shallow, not deep as in *rufifemur*.

Moreover, the hind tibiae of the former species are centrally whitish not rufescent. *E. geniculatum* is a smaller species, 6 mm. long, closely resembling *E. albidum*, but with the hind femora very distinctly black at their apices. It has a close resemblance to *crassifemur* and the femora are almost equally large, but the whitish centre of the hind tibiae will usually distinguish it. The lateral petiolar sulci are fine, but this is a difficult and unsatisfactory character.

E. rufifemur was found to be a common internal larval parasite of *buoliana*, from which it had not previously been recorded. It was obtained both from Suffolk and the New Forest. It rarely emerges from the pupa. Emergence took place from early June (the males perhaps even earlier) to 9th July. Females were found to be slightly in excess—59 per cent. The specific characters of the larva have already been mentioned; they give further evidence of the close relationship between *Omorgus* and *Eulimneria*. The cocoons of *Eulimneria* are rather distinctive, in that they are made of unusually white silk and show a darker band around the middle. The insect is known from North and Central Europe. The only recorded host appears to be *Rivula sericealis*, Scop., in Germany.

Of the other Ophionine parasites recorded, *Pristomerus* can be easily identified by the well-marked median teeth on the underside of the hind femora, while *Angitia* is characterised by the strongly post-furcal vertical nervellus coupled with the flat petiolar area.

The genus *Pimpla* contains a large majority of the Pimpline parasites of *buoliana*. The useful key given by Morley (iii, p. 53) covers the females and some of the males

* In some specimens of *crassifemur* the black spot on the apex of the femur is lacking.

of all save one of the species with which we are concerned. A separate key for the males is given by Schmiedeknecht, but in several species these still remain undescribed, so that the key is of limited value.

Pimpla ruficollis, Grav.

A predominantly red species, 6–9 mm. in length, with a very long (9 mm.) ovipositor. It resembles the smaller *P. pomorum* superficially, but has a longer ovipositor. Emergence commenced on 2nd July and continued until 21st August. It is an external larval parasite and also an external hyperparasite through *Omorgus mutabilis* and probably *Eulimneria rufifemur*, and other species. The primary larva of *P. ruficollis* is 2 mm. in length and consists of a slightly chitinised head capsule (fig. 8, b) and thirteen body segments, each bearing a ring of a few fine setae. The mandibles lack the setae present on those of the fully grown larvae.

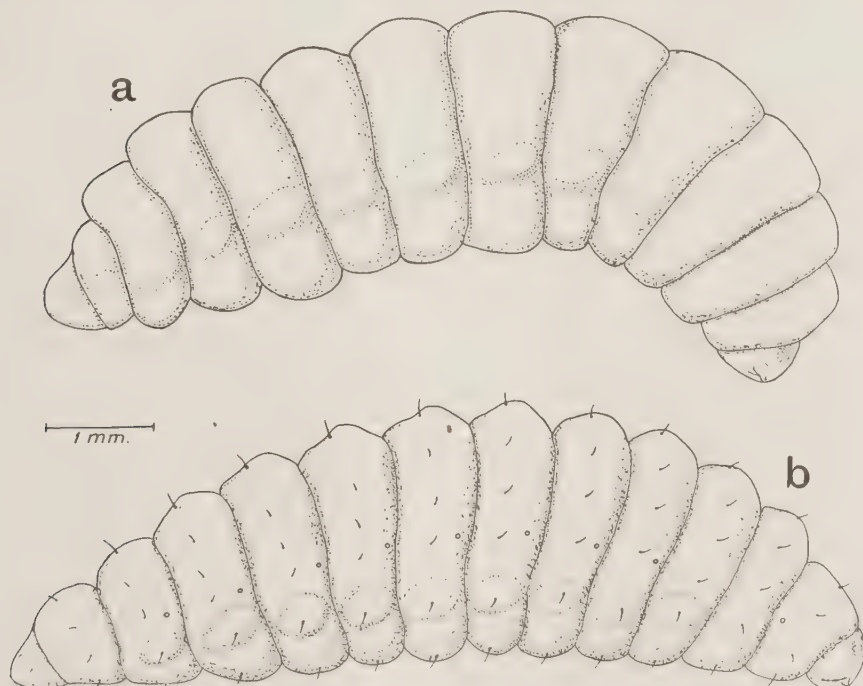


Fig. 1. Mature larva of : (a) *Omorgus mutabilis*, Holmg. ; (b) *Pimpla ruficollis*, Grav.

The mature larva (fig. 1) is of a common Pimpline type, of which the well chitinised labial ring with fine ventral teeth, the arrangement of the struts, the setose mandibles, and the conspicuous antennae are typical. Each segment of the body bears a ring of well developed setae. The tracheal system is of the normal Ichneumonid type, *i.e.*, with an accessory longitudinal tracheal commissure lying in the thoracic segments ventral of the tracheal trunk, and there are ~~nine~~ pairs of spiracles, the second pair being minute (0.023 mm. diameter). This vestigial pair of spiracles on the second postcephalic segment was first described by Imms in *P. pomorum* and is in all probability generally present in the group, having previously been overlooked. The spiracles, at least in the three common species here dealt with, also provide good

distinguishing characters (fig. 2). Before pupation the larvae usually spin a light irregular cocoon, characteristic of the Pimplines and quite distinct from that of the Ophionines, but not infrequently when placed in the gelatin capsules for rearing they would remain completely naked.

The male of *P. ruficollis* is unknown, and among the great numbers of the species bred during the course of this work no males were obtained.



Fig. 2. Spiracles of mature larva of: (a, b) *Pimpla examinatore*, F.; (c) *Pimpla ruficollis*, Grav.; (d) *Pimpla brevicornis*, Grav. $\times 233$.

The species is widely distributed throughout North and Central Europe. It was present in both Suffolk and Hampshire. It has long been known as a parasite of *R. buoliana* and in addition has been recorded from the following hosts:—

- TORTRICIDAE. *Argyroplote mulsantiana*, Ratz.
Argyroplote nordlingeriana, Ratz.
Eucosma tripunctana, F.
Peronea (Rhyacionia) pinivorana, Zell.
P. (R.) turionana, Hübner.
- CYNIPIDAE. *Andricus* sp.
 " *Cynips terricola*."

Pimpla brevicornis, Grav.

This insect is a fairly common external larval parasite of *buoliana*, 6–9 mm. in length, emerging from 20th June to 24th July. The larvae can be distinguished from those of the preceding species without great difficulty, the shape of the mandibles and of the labial struts being characteristic (fig. 6, c).

There is much uncertainty with regard to the sex ratio in this species. According to Morley, males of both *P. inquisitor* and *P. brevicornis* are very rare. In our material, however, we have six females and 82 males attributable to the latter species. It is true that the distinction of the males of these two is at present practically impossible, but since we did not rear a single female of *inquisitor* from *R. buoliana* they are presumably *P. brevicornis*. In the material from Hampshire males only were present. The females we have reared are all of the typical form, save that the stigma is strongly infuscate. The males, however, have the coxae pale yellow or red and the palpi, in many cases, almost white, although the stigma is infuscate as in the female.

P. brevicornis is a common species throughout North and Central Europe and was long ago recorded as a parasite of *buoliana*, although Morley regards this as an error for *Pimpla (Scambus) sagax*, Htg. Van Burgst (1919), however, records both *P. brevicornis* and *P. sagax* as parasites of *buoliana*. Other hosts from which it has been reared are as follows:—

- PIERIDAE. *Leucophasia sinapis*, L.
- GEOMETRIDAE. *Eupithecia linariata*, F.
- TINEIDAE. *Aristotelia pulveratella*, H.-S.
- TORTRICIDAE. *Coleophora frischella*, L.
Polychrosis euphorbiana, Frey.
Tortrix forsterana, F.
- TENTHREDINIDAE. *Ardis brunniventris*, Htg.

It has also been recorded "from the pupa of a beetle," and there are records from *Anthonomus pomorum*; Brischke claims to have reared it from *Apanteles congestus*, Nees, but this record appears so improbable that confirmation is needed before it can be accepted.

Pimpla elegans, Woldst.

This is a rare larval parasite of *buoliana*, two males and two females having been reared. The males have long been known under the name *Troctocerus elegans*, the genus having been erected to accommodate the one species of which males only were known. The distinguishing character of the genus was the dilatation of the second to the fourth funicle segment of the antennae on the underside. No hosts were known.

In 1927, A. Seyrig described a female Pimpline from a Tineid, *Phyllobrostitis ermitella*, Joannis, and a Tortricid, *Pamphne juniperana*, Millière, as *Scambus cotei*, sp. n., but shortly afterwards obtained the males, which proved to be the insect previously known as *Troctocerus elegans*, Woldst.

The description of the female given by Seyrig is as follows :—

"♀. Tête arrondie, vue de face, les yeux touchant presque les mandibules. Tempes larges, à peine rétrécies en arrière, brillantes, ainsi que la face, faiblement et très éparsement ponctuées, revêtues d'une pubescence blanche. Antennes filiformes, ayant environ la longueur de l'abdomen. Funicle de 21 articles. Mésonotum et écusson ponctués comme la tête. Sillons parapsidaux distincts, se prolongeant par une zone, un peu plus fortement ponctuée que le reste. Métathorax brillant, faiblement ponctuée en dessus, rugueux sur les côtés. Abdomen exactement linéaire, les segments 2-6 également larges; le premier transversal, 2 et 3 carrés. Ponctuation assez forte. Bord postérieur des segments lisse. Tubercules très faiblement indiqués. Tarière à peine plus court que le corps. Nervellus brisé en son tiers inférieure. Ongles des pattes dentés. Taille 6-5 mm."

The distinction of the insect from *P. ruficollis* and *P. pomorum* is a difficult matter, and our females were at first mistaken for the latter species. The following key, kindly constructed for me by Dr. C. Ferrière, gives the most reliable characters for the separation of the three species.

Key to the Females.

1. Tarsal claws not dentate; nervellus intercepted in the middle, or a little above or below; ovipositor little shorter than the body; antennae with 23-27 segments *P. ruficollis*, Grav.
Tarsal claws dentate below; nervellus intercepted far below the middle 2.
2. Antennae with 23 segments; abdomen with segments 2-4 subquadrate, the ovipositor about as long as abdomen and thorax combined *P. elegans*, Woldst.
Antennae with 20 segments; abdomen with all the segments transverse; the ovipositor not longer than the abdomen *P. pomorum*, Ratz.

Key to the Males.

1. Antennae with second to fourth funicle segments dilated beneath; front femora bi-emarginate; abdomen elongate, the segments about twice as long as broad *P. elegans*, Woldst.
Antennae with all funicle segments cylindrical; front femora normal; abdomen short, segments 2-4 subquadrate *P. pomorum*, Ratz.
(♂♂ of *P. ruficollis*, Gr., not certainly known.)

Other closely related species, *P. cercopithecus*, Costa, *P. erythronota*, Kr., and *P. taschenbergi*, deG., have not yet been found in England and are not known to us. They can readily be distinguished by Schmiedeknecht's key; Seyrig (1927) has also given a comparison of *P. elegans*, Woldst., with *P. cercopithecus*, Costa.

Pimpla elegans has been recorded from Silesia, Austria, Spain, and Central France. It is new to Great Britain and has not hitherto been recorded from *buoliana*.

Pimpla sagax we have not obtained. It is a species the females of which are not well known and it is said to resemble *brevicornis*; it seems not improbable that the specimens previously recorded as parasites of *buoliana* may in reality have been *brevicornis*. The males of *sagax* are, however, quite distinct in the emarginate front femora and the strongly curved front tibiae. None of our supposed *brevicornis* males shows the character.

Pimpla examiner, F.

This species belongs to the second big sub-division of the genus characterised by the non-emarginate clypeus, the nervellus intercepting below the centre, and by the usually elongate metathoracic spiracles. The great majority of species in this group are internal pupal parasites. Two others, *turionellae* and *alternans*, are known as *buoliana* parasites. The specimens reared from *buoliana* vary considerably in the sculpture of the metathorax and the degree of development of the white ring on the hind tibiae. Some individuals in this respect approach the species *P. bilineata*, Brullé, which Morley regards as a synonym, and there seems no good line of distinction between the two. The males vary from 6 to 8 mm. in length; the females from 7 to 12 mm.

P. examiner was by far the commonest pupal parasite obtained and was also the first to emerge, appearing from 13th June to 11th July. From the time of emergence and the fact that it attacks the pupae, one may be certain that an alternative host is required. In view of the long host list given below, there are obviously many possibilities, and it is not likely that the insect has any difficulty in finding a suitable species which passes the winter as a pupa.

The illustrations show at a glance the striking differences in larval structure between *examiner* and the other *Pimplines* (figs. 2, 6, 8). I have also examined specimens of *P. instigator*, which have been reared extensively in this laboratory on *Pieris napi* and other pupae, and find that it agrees closely with *P. examiner* in all essential points.

The other species of *Pimpla* (*ruficollis*, *brevicornis*, and *pomorum*) of which larval descriptions are available all belong to the first group, which are external parasites of larvae, and the differences between these two groups are very interesting. The internal pupal parasites can be told at a glance by the absence of body setae, the presence of large flanged mandibles, which are very broad basally, and by the fusion of the labral struts to form a broad pigmented dorsal arch. The fusion of the mandibular struts is also characteristic. In addition, one may mention the distinctive character of the labial and maxillary sensillae (figs. 5, 6) and the presence of spiny processes in the region of the hypopharynx (fig. 6, *b*). These differences in larval habit and structure, coupled with those of the adult already known, seem to the writer to be quite sufficient to warrant the division into two or more genera or sub-genera. Such a course, which was adopted by earlier workers (e.g., Thomson), not only seems justified from the morphological and biological standpoint, but in view of the large size of the genus *Pimpla*, as at present constituted, would be convenient for purely systematic reasons.

In our rearings males and females appeared in approximately equal numbers (53:47). This is of some interest in view of Morley's statement that the females must be very rare in Britain (iii, p. 99).

This insect is of general European distribution. It is known as a *buoliana* parasite on the Continent, but has not previously been recorded as such from Britain. It was found in the New Forest as well as in Suffolk. The recorded hosts are as follows :—

CURCULIONIDAE.	<i>Anthonomus pomorum</i> , L.
NYMPHALIDAE.	<i>Vanessa polychloros</i> , L.
	<i>V. urticae</i> , L.
PIERIDAE.	<i>Aporia crataegi</i> , L.
ARCTIIDAE.	<i>Oeonistis quadra</i> , L.
	<i>Phragmatobia fuliginosa</i> , L.
NOCTUIDAE.	<i>Cucullia argentea</i> , Hufn.
	<i>Noctua plecta</i> , L.
	<i>Phytometra gamma</i> , L.
LYMANTRIIDAE.	<i>Lymantria monacha</i> , L.
	<i>Nygmia phaeorrhoea</i> , Don.
THYATIRIDAE.	<i>Palimpsestis octogesima</i> , Hübn.
NOTODONTIDAE.	<i>Dicranura vinula</i> , L.
	<i>Thaumetopoea processionea</i> , L.
GEOMETRIDAE.	<i>Abraxas grossulariata</i> , L.
	<i>Ennomos quercinaria</i> , Hufn.
PSYCHIDAE.	<i>Acanthopsyche opacella</i> , H.-S.
	<i>Pachytelia unicolor</i> , Hufn.
	<i>Psyche calvella</i> , Ochs.
	<i>P. graminella</i> , Schiff.
	<i>P. hirsutella</i> , Hübn.
	<i>P. viciella</i> , Schiff.
LASIOCAMPIDAE.	<i>P. stettinensis</i> , Hering.
	<i>Lasiocampa trifolii</i> , Esp.
	<i>Malacosoma neustria</i> , L.
PYRALIDAE.	<i>Loxostege sticticalis</i> , L.
	<i>Nephopteryx genistella</i> , Dup.
	<i>N. vacciniella</i> , Zell.
AEGERIIDAE.	<i>Trochilium scoliaeformis</i> , Borkh.
TINEIDAE.	<i>Carcina (Tortrix) quercana</i> , F.
	<i>Fumea casta</i> , Pall.
	<i>Hyponomeuta cognatellus</i> , Hübn.
	<i>Hyponomeuta malinellus</i> , Zell.
	<i>Hyponomeuta padellus</i> , L.
TORTRICIDAE.	<i>Ornix torquillella</i> , Z.
	<i>Cacoecia piceana</i> , L.
	<i>Clysia ambiguella</i> , Hübn.
	<i>Tortrix viridana</i> , L.
	<i>Sparganothis pilleriana</i> , Schiff.

The remaining Pimplines do not require more than passing mention.

P. robusta, Morl.—Two female specimens only ; 17th and 29th June. There are no previous rearing records for this species.

P. detrita, Holmg.—One specimen. This insect has been recorded from a variety of Lepidopterous hosts, including *R. buoliana*, as well as from *Lipara lucens*, Mg. (Diptera, Chloropidae), but, according to Morley, all the early host records are

unreliable owing to confusion, on the Continent, with *P. graminellae* and other allied species. Dr. G. Salt has, however, reared it from *Cephus pygmaeus* in this laboratory.

Clistopyga incitator, F.—A single female of this species, 6–7 mm. in length, was reared from pine shoots containing *R. buoliana*, from which it had probably come. It has previously only been recorded from *Rhyacionia resinella*, L., and from galls of *Cynips kollari*, Htg.

Lissonota transversa, Bridg.—A single female, 7 mm. in length. According to Morley, this is one of the commonest British species of the genus, but in spite of this no hosts were previously known. According to Schmiedeknecht, the female can readily be distinguished from *L. humerella*, Thoms., by the dart-shaped, not rounded, yellowish white marks on the mesonotum. The three genera *Lissonota*, *Lampronota*, and *Glypta* can be distinguished from *Pimpla*, as Cushman & Rohwer (1920) point out in their valuable key to the tribes of the ICHNEUMONIDAE, by the ovipositor being dorsally notched a short distance back from the apex. *Lampronota* has the meta-thoracic spiracles elongate, whereas in *Lissonota* they are small and circular, or, if somewhat oval, oblique. *Glypta* can be distinguished from these two genera by the oblique furrows on the tergites. *Exetastes cinctipes* belongs to a group (BANCHIDES) of very uncertain position. Schmiedeknecht places it in the Ophionines, Morley among the Pimplines. From the remaining Pimplines it can be separated by the large rhomboidal areolet and short terebra. In *Exetastes* the eyes are not internally emarginate and the claws are simple. *E. cinctipes*, a slender black and red species, is one of the commonest British Ichneumons and is normally a parasite of Noctuid larvae. It can, as a rule, be separated from the other British species by the red hind metatarsus.

The ICHNEUMONINAE reared do not require more than passing mention. The genus *Phaenogenes* can, as a rule, be distinguished from *Ichneumon* by the metathoracic spiracles being circular and not linear or ovate.

Two species of *Phaenogenes* were reared, but with the material available it is not possible to make certain identifications. A single small male, probably *Phaenogenes mysticus*, was reared on 9th July from *buoliana* larvae and pupae, isolated from pine-shoots on 16th June and placed in an incubator at 26° C., and a single female of *Phaenogenes* sp., probably *coryphaeus*, was reared on 3rd July from parasite cocoons isolated from infested pine-shoots.

None of the CRYPTINAE reared was of frequent occurrence. Two females of *Hemiteles bicolorinus*, Grav., emerged on 21st June and 6th July from cocoons and larvae picked out from pine-shoots. It has not previously been recorded from *buoliana*. It is in all probability a hyperparasite. Its host list is as follows:—

LYMANTRIIDAE. *Porthetria dispar*, L. (via *Microgaster*).

LASIOCAMPIDAE. *Lasiocampa quercus*, L.
Malacosoma neustria, L.

TINEIDAE. *Coleophora tiliella*, Zell.
Fumea intermediella, Brd.
Lyonetia clerckella, L.
Endrosis lacteella, Schiff.
Scythropia tenella, Zell.
S. crataegella, L.

CYNIPIDAE. *Cynips kollari*, Htg. (bred from galls).

BRACONIDAE. *Apanteles congestus*, Nees.

ANTHOMYIIDAE. *Limnophora* (*Calliophrys*) *riparia*, Fall.

A single male attributable to *Hemiteles palpator*, Grav., was also obtained from this material (6th July 1928), as were other male *Hemiteles*, not at present identifiable with certainty. The known hosts of *H. palpator* are as follows:—

SATURNIIDAE.	<i>Saturnia carpini</i> , Schiff.
TINEIDAE.	<i>Coleophora fuscadinella</i> , Zell.
	<i>C. frischella</i> , L.
	<i>C. vibicella</i> , Hübn.
	<i>Taleporia pseudobombycella</i> , Hübn.
TORTRICIDAE.	<i>Phalonia atricapitana</i> , Steph.

An interesting species, of which a single individual was obtained was *Gelis fallax*, Forst. This is a species recorded from Germany and France. Dr. C. Ferrière tells me that it is quite common in the latter country. It appears to be new to the British list. There are no previous host records and nothing definite is known as to its biology.

A single male specimen of a pupal parasite, which was reared, appears to be *Hypsantyx impressus*, Grav. It is also new to this country. It is a rare insect, previously reported from various parts of North and Central Europe. According to Schmiedeknecht, it attacks various *Lophyrus* spp.

Of the five species of BRACONIDAE reared, only one, *Orgilus obscurator*, Nees, appears to be of any great economic importance. It is a black species, 5–6 mm. in length, with dusky wings and reddish legs, the female with a slender, slightly curved ovipositor about the length of the abdomen. There is some uncertainty about the exact systematic position of the genus and it has been placed in the MACROCENTRIDAE. Although placed in the old division AREOLARI by Marshall, it is aberrant in that there are only two cubital cells, the small second cubital (R4 of Comstock and Needham), which resembles the areolet of the ICHNEUMONIDAE and which is usually the most obvious distinguishing characteristic of the AREOLARI being undifferentiated. This, however, is equally true of certain other genera normally placed in this division. The rather shallow, but distinct, parapsidal furrows, in conjunction with the short radial cell, indicate its place in the tribe AGATHINAE.

The European species of *Orgilus* are mainly parasites of PSYCHIDAE, *obscurator* being the only one recorded from a variety of Lepidopterous hosts.

Orgilus is everywhere a very common internal larval parasite, which also commonly emerges from the pupa. It was emerging from 29th June to 7th August. Very possibly certain of the common double-brooded insects mentioned in the list below (e.g., *Anacamptis anthyllidella* on *Anthyllis*, etc.; *Mompha miscella*, on *Helianthemum*; or *Gelechia acuminatella*, on *Carduus* and *Centaurea*) may serve as alternative hosts.

The early larval forms are of the well-known Braconid type as described in *Apanteles melanoscclus*, Ratz., by Crossman in 1922 (C. C. Brooks). A caudate larva, with a well chitinated head and large sickle-shaped mandibles is succeeded by a vesicle-bearing form of the usual type.

The mature larva may be distinguished from the other common internal parasites of *buoliana* by the absence of the ventral longitudinal tracheal commissure, a Braconid characteristic long ago pointed out by Seurat. Our knowledge of larval mouth-parts (figs. 4, b; 7, c) hardly justifies us in saying which are the definitely Braconid features, but the sickle-shaped mandible, with a well developed row of teeth, and the slender labial ring, as well as the faintly pigmented but continuous over-arching strut, make separation from the other species described easy. The small cocoon of thick white silk is quite distinct from those of the other common *buoliana* parasites.

The sexes of *O. obscurator* were present in approximately equal numbers. The species is widely distributed throughout Europe, as far south as Italy and Corsica. It has been recorded from a variety of hosts as follows :—

TINEIDAE.	<i>Anacamptis anthyllidella</i> , Hübn.
	<i>Coleophora alcyonipennella</i> , Koll.
	<i>C. discordella</i> , Zell.
	<i>C. niveicostella</i> , Fisch.
	<i>Depressaria conterminella</i> , Zell.
	<i>D. liturella</i> , Hübn.
	<i>Gelechia acuminatella</i> , Sircom.
	<i>Mompha miscella</i> , Schiff.

TORTRICIDAE.	<i>Argyroplote mygindana</i> , Schiff.
	<i>Evetria resinella</i> , L.

Mr. S. Garthside tells me that he has also reared it in this laboratory from the Tortricid, *Lathronympha hypericana*, Hübn.

The genus *Microbracon* falls in the division Cyclostomes and in consequence can easily be separated from the other Braconid parasites by the deeply hollowed labrum, which, in conjunction with the curved mandibles, gives the appearance of a circular mouth-opening.

M. discoides, Wesm., is a mainly black insect of about 6 mm. in length, with slightly dusky wings and having the mandibles, the palpi, and the lateral border of all the abdominal segments testaceous. Four specimens were obtained from the New Forest. The species is known from Britain, Belgium, and France, and in the latter country has been recorded as a parasite of *R. buoliana* by Feytaud. Marshall gives the following varied host list :—

CURCULIONIDAE.	<i>Byctiscus betulae</i> , L.
	<i>B. populi</i> , L.
	<i>Curculio (Balaninus) pyrrhoceras</i> , Marsham.

TENTHREDINIDAE.	<i>Pontania viminalis</i> , L.
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The remaining Braconids are of little importance. *Microbracon abscissor*, Nees, of which a single female was obtained on 29th June 1928, appears to be new to the British list. It closely resembles *M. discoides*, from which it can be distinguished by the mainly reddish-yellow colour of all the abdominal segments except the first. It has been previously recorded from Bavaria and Russia. In the latter country it was obtained from a Noctuid, *Oria musculosa*, Hbn. The male is unknown.

Apanteles falcatus, Nees. A single female was reared on 12th June. It is a common species known from widely separated European localities and from North Africa, and is known to parasitise the common Noctuid, *Xylophasia monoglypha*, Hübn.

Eubadizon extensor, L. A single female of this curious elongate insect (9–12 mm.) was reared on 29th June 1928, from a cocoon isolated from infested pine-shoots. It is a common widespread species in Europe and is recorded from a number of Lepidopterous hosts as follows :—

NOCTUIDAE.	<i>Earias chlorana</i> , L.
TINEIDAE.	<i>Depressaria nervosa</i> , Haw.
	<i>Hypatima gibbosella</i> , Zell.

- TORTRICIDAE. *Argyroplote nordlingeriana*, Ratz.
 A. bifasciana, Haw.
 A. mulsantiana, Ratz.
 Eucosma immundana, Fisch.
 E. penkleriana, F.R.
 Tortrix crataegana, Hübn.
 T. diversana, Hübn.
 T. rosana, L.
 T. viridana, L.

Habrocytus acutigena (PTEROMALIDAE), the commonest hyperparasite emerged from 30th July till 21st August. In our material it was chiefly, perhaps almost entirely, a parasite of *Cremastus interruptor*. Females were greatly in excess. Voukassovitch (1927) has described *Habrocytus* sp. as ectoparasitic on the larvae of Braconids (such as *Apanteles*) inside the cocoon. It has also been reared from *Polychrosis botrana*, Schiff., in Germany and Austria, and from *Clysia ambiguella*, Hübn.

Some half dozen specimens of a species of *Eutelus*, thought by Dr. Masi to be *E. mediterraneus*, Mayr, were also obtained, but no observations as to its biology were made. The record is interesting, however, in that it has previously been known from the south of Europe only. It is polyphagous, having been bred from Cecidomyiid galls as well as from Lepidopterous larvae.

Small numbers of a single species of egg-parasite, *Trichogramma evanescens*, were obtained. This insect, as is well known, parasitises a very great number of Lepidopterous and other insect eggs. The strain obtained from *R. buoliana* was found to be thelytokous; it was propagated by Mr. J. W. Evans for a long period in the laboratory, but eventually died out.

A single specimen of a Tachinid, *Actia nudibasis*, Stein, was reared by Mr. Baird from the material shipped to Canada and another solitary specimen was obtained from the New Forest. This species has been confused with *pilipennis*, Fall., from which, however, it can be distinguished by the fact that the first longitudinal vein has the basal two-thirds bare and is setose on the apical portion only (Wainwright, 1928). *A. pilipennis*, Fall., has previously been recorded as a parasite of *R. buoliana* in Europe and is also known from a number of other Tortricids, Pyralids and Tineids, including:—

- PYRALIDAE. *Dioryctria abietella*, F.
 D. splendidella, H. S.
- TINEIDAE. *Depressaria costosa*, Haw.
 D. liturella, Hübn.
 Hyponomeuta euonymellus, L.
- TORTRICIDAE. *Olethreutes schulziana*, F.
 Evetria resinella, L.
 Sparganothis pilleriana, Schiff.
 Tortrix pronubana, Hübn.
 T. viridana, L.

Owing to the confusion of the two species there can be little doubt that some of the above records refer to *A. nudibasis*, Stein.

Only one other British specimen of *nudibasis* is known (Wainwright, 1928).

5. Morphology of the Head of last stage Larvae of Ichneumonidae and Braconidae.

The illustrations of the larval mouth-parts show the characters which are specifically important, but a few words may be said as to the homologies of the

various parts. So few of the great host of Ichneumonid larvae are yet known that the conclusions are bound to be merely tentative.

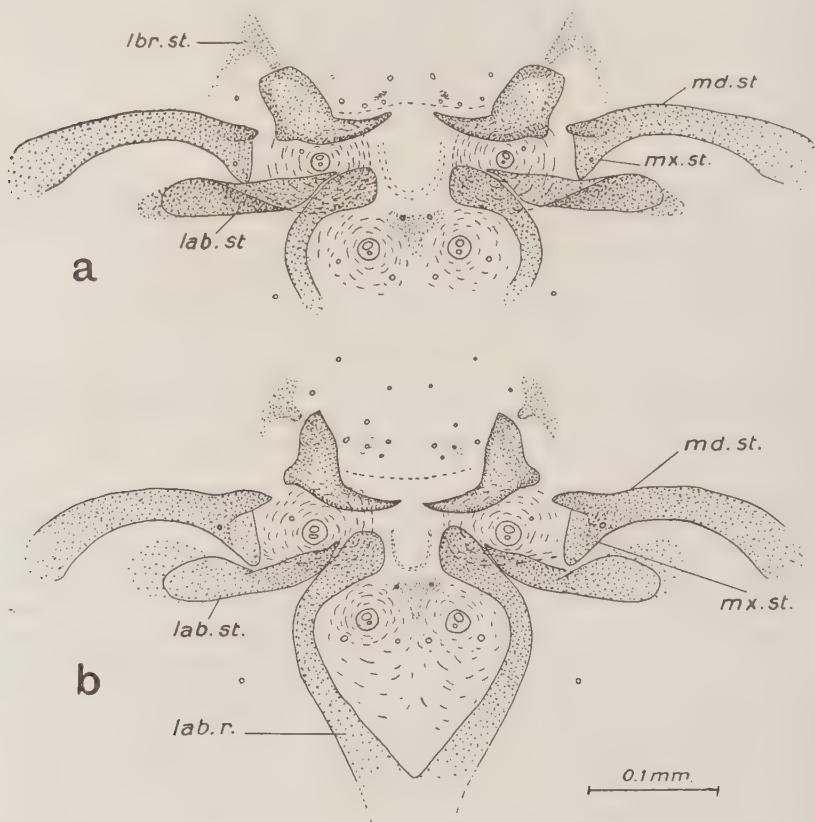


Fig. 3. Front view of face of mature larva of: (a) *Omorgus borealis*, Zett.; (b) *O. ensator*, Grav.

<i>a</i>	...	antenna	<i>mx.s.</i>	...	maxillary sensillae
<i>ph.tr.</i>	...	pharyngeal trough	<i>mx.st.</i>	...	maxillary strut
<i>lbr.s.</i>	...	labral sensillae	<i>lab.s.</i>	...	labial sensillae
<i>lbr.st.</i>	...	labral strut	<i>lab.st.</i>	...	labial strut
<i>md.</i>	...	mandible	<i>lab.r.</i>	...	labial ring
<i>md.st.</i>	...	mandibular strut			

The following elements can be distinguished in all the species and appear to provide the ground plan of tentorial structures in the ICHNEUMONIDAE.

Mouth-parts: Labrum, mandibles, maxillary palpi, labial plate, labial palpi.

Tentorium: Labral strut, mandibular strut, maxillary strut, labial strut, labial ring.

The use of these names does not necessarily imply any homology with structures found in the adult. They have been adopted as convenient in consultation with

Dr. G. Salt, who has in preparation a detailed description of the various parasites of *Cephus pygmaeus*, L., and it is hoped that they will be found applicable to the larvae of the Parasitica as a whole.

Taking *O. borealis* first, as typical of the Ophionines, we have the mandibles (*m*) articulated with the labral and mandibular struts (*lbr. st.* and *md. st.*). The labrum is not "sclerotised" and is merely the ridge above the mouth, bearing sensillae. The labral strut is very faintly "sclerotised," and the lower is heavily "sclerotised" and pigmented. The former is, in some species, much more highly developed and may touch, or fuse with, the latter. The mandibular strut is typically Y-shaped, with a long stem and short arms. It is perhaps the most important of the tentorial structures. In some forms (e.g. *Orgilus obscurator*), the two mandibular struts are continued backwards and fused with each other posteriorly to form a supporting

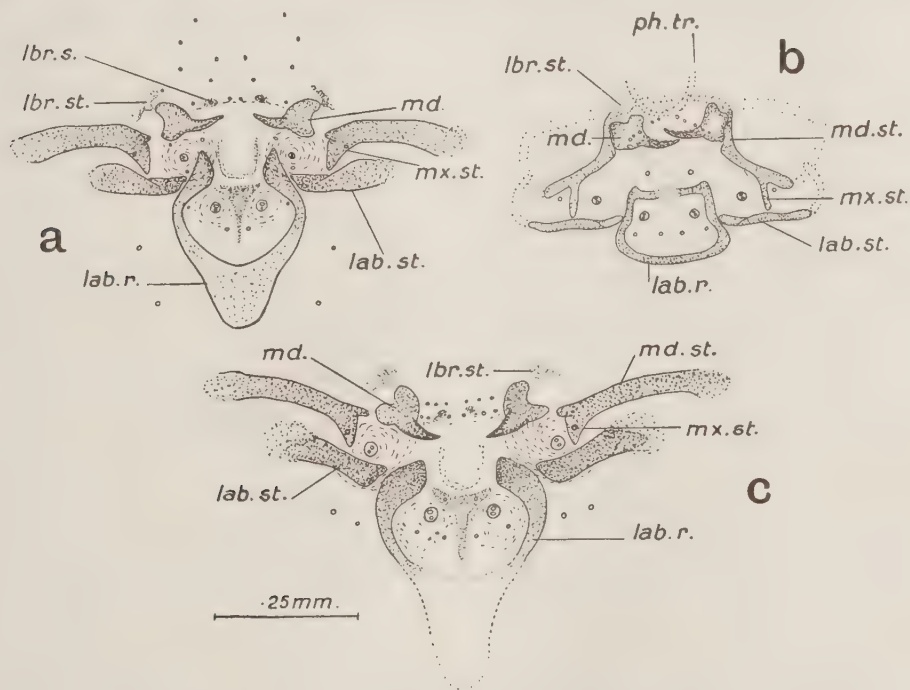


Fig. 4. Front view of face of mature larva of: (a) *Eulimneria rufifemur*, Thoms.; (b) *Orgilus obscurator*, Nees; (c) *Omorgus mutabilis*, Holmg.

ring; in others (e.g. *Cremastus interruptor*) they may have internally projecting flanges, not visible in face view or in preparations made from cast skins. The upper arm is merely a condyle which articulates with the mandible. The lower arm, which in some forms is more strongly developed, is the maxillary strut. Basally the mandible is triangular in section, two of the angles being articulated as described above, and the third (internal) angle is a point of attachment of a flexor muscle. The labial ring is a conspicuous pigmented strip surrounding the labial area below the mouth. This area bears two conspicuous sense-organs which may perhaps represent the labial palps. A Y-shaped pigmented patch is a conspicuous feature

in the labial area of *Eulimneria* and certain species of *Omorgus*. The shape of the ends of the open labial ring and the degree of pigmentation ventrally often provide good specific characters. On each side of the labial ring lies a simple labial strut (*l.s.*), the inner ends of which almost reach the labial ring. The more important sense-organs are as follows: A pair of antennae, situated well above the upper mandibular struts, each consisting of a single conical tubercle in the centre of a smooth non-chitinised area; a pair of maxillary sensillae (*mx. s.*), situated on slightly raised areas just below the bases of the mandibles; and a pair of similar organs, the labial sensillae (*lab. s.*) within the labial ring. These sensillae probably represent labial and maxillary palpi. They are identical in structure in a given species. They consist of two or more sensory (?) papillae surrounded by a pigmented ring, and seen mounted under a high power provide good characters. There are also many other sensory (?) hairs grouped about the head, but except for those within and immediately adjacent to the labial ring, these were found to be extremely variable in number and

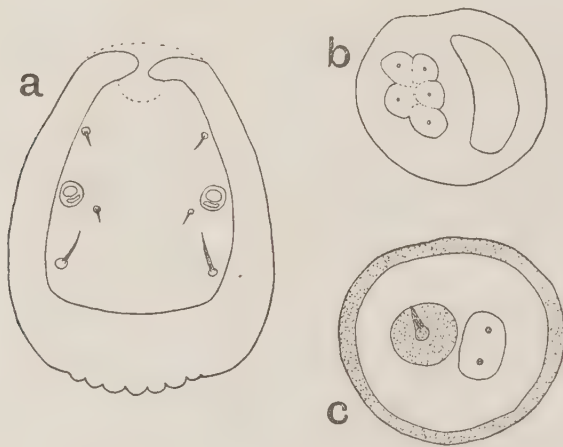


Fig. 5. Details of mature larvae: (a) labial ring and plate of *Pimpla ruficollis*, Crav., $\times 216$; (b, c) labial sensilla of, respectively, *Pimpla examinador*, F., and *Eulimneria rufifemur*, Thoms., $\times 1200$.

position and are quite useless for systematic work. The most conspicuous of these lie on the labral ridge, and in *Cremastus interruptor* there are two groups of them, each within a pigmented ring and thus somewhat resembling a maxillary or labial palp of the type found in *Pimpla examinador*.

The differences between the various species of Ophionines are described above.

Taking *P. ruficollis* as typical of one group of PIMPLINAE, the same essential parts can be distinguished. The mandible is similar in structure, but the tooth is only slightly curved and bears two rows of stiff bristle-like hairs (fig. 7, a). The labral struts (fig. 8, a) are more strongly developed and the maxillary struts are produced downward almost to the edge of the labial ring. The labial strut in this species is vestigial; it runs across from the base of the mandibular strut to the lower end of the maxillary strut. In *P. pomorum* (see Imms, 1918) it is fused to the base. The broad, well pigmented labial ring (fig. 8, a) is characteristic of this group of Pimplines.

It is nearly closed above and bears three or five well rounded lobes on its lower margin, which is well pigmented.

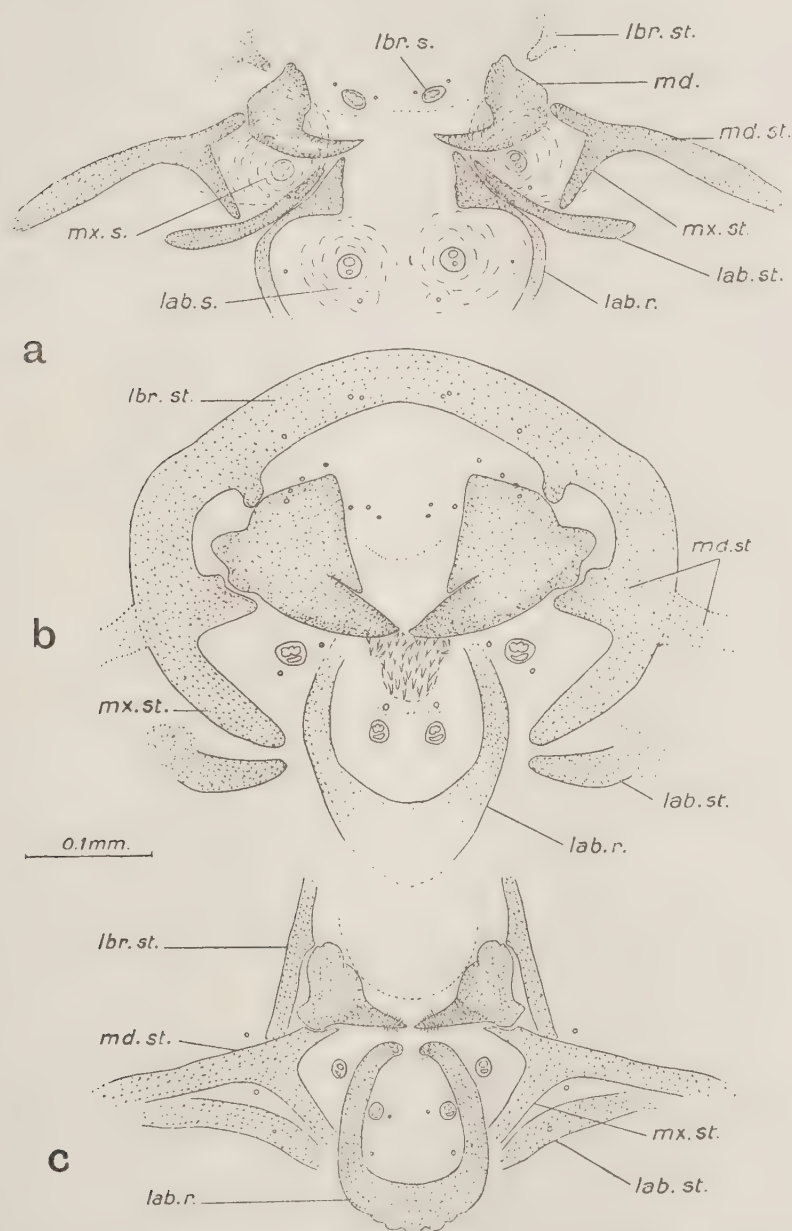


Fig. 6. Front view of face of mature larva of : (a) *Cremastus interruptor*, Grav. ; (b) *Pimpla examinador*, F. ; (c) *Pimpla brevicornis*, Grav.

The very distinctive characters shown in *P. examiner*, as mentioned above, appear to be characteristic of the group of Pimplines which are internal pupal parasites. Apart from the mandibles, which lack setae and have a broad basal flange, these forms differ markedly (1) in the presence of a spiny hypopharyngeal region (fig. 6, *b*) ; (2) in the structure of the labial and maxillary palpi ; and (3) in the fusion of the labral struts with each other and with the mandibular and maxillary struts, to form a broad over-arching hoop. The mandibular strut is very slightly developed laterally.

This labral arch is essentially similar to that which is typically found in the Braconids and which has been described by Genieys (1925) in *Microbracon*. *Orgilus*

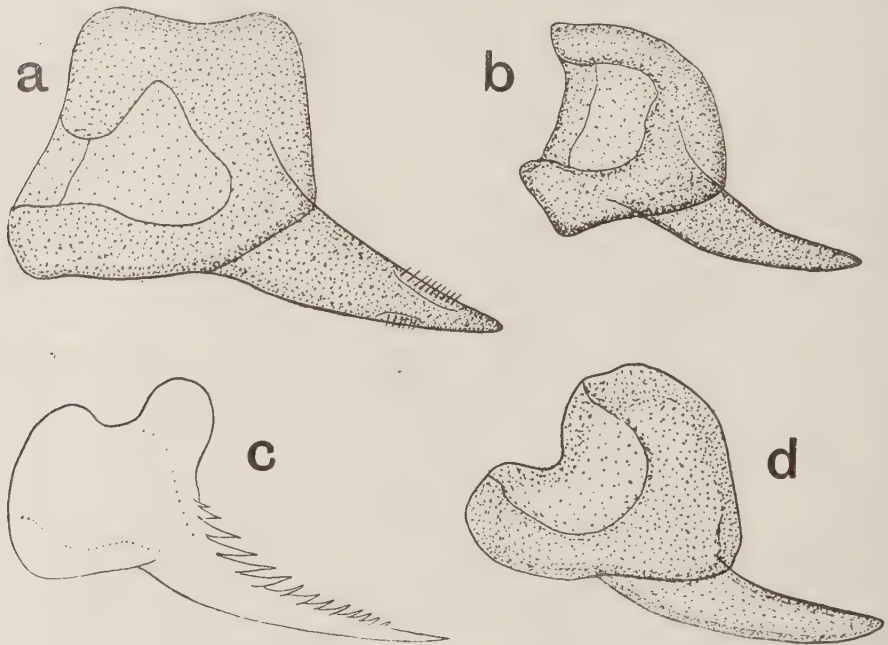


Fig. 7. Left mandible, from behind, of mature larva of : (a) *Pimpla ruficollis*, Grav. ; (b) *Eulimneria rufifemur*, Thoms. ; (c) *Orgilus obscurator*, Nees ; (d) *Omorgus mutabilis*, Holmg., $\times 467$.

obscurator (fig. 4, *b*) conforms to this type but appears exceptional in that the arch is very faintly pigmented and is difficult to see without staining. The maxillary strut in this species is attached to the mandibular at this point, far back from the mandibular condyle. The sickle-shaped mandible, with its rows of teeth, is perhaps the exclusively Braconid character.

It is clear from this work that in many cases the larvae do provide a variety of specific characters, and more extensive work on larval morphology, even in groups in which superficially the larvae appear devoid of characters, is certain to yield results of great value to the systematist, particularly with regard to the definition

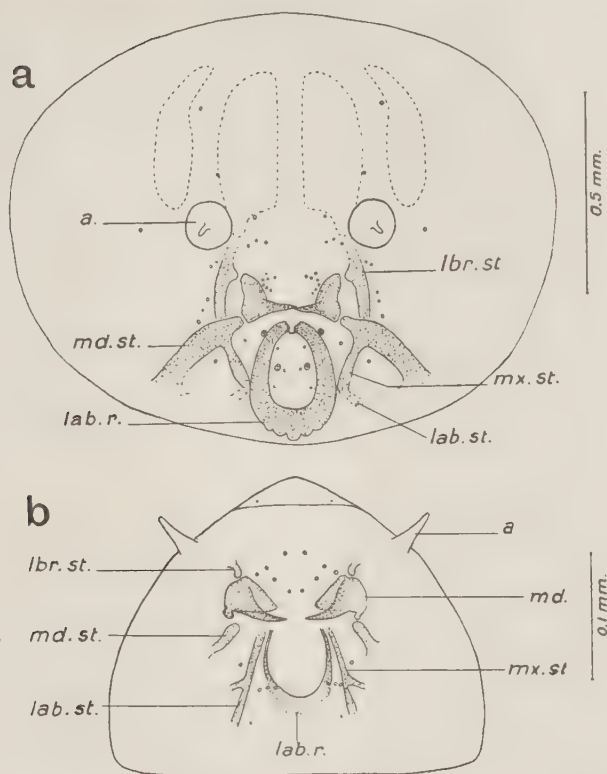


Fig. 8. *Pimpla ruficollis*, Grav., front view of head of: (a) mature larva; (b) 1st stage larva.

of genera and higher groups. The description of a species of insect cannot be considered as complete, nor in many cases its correct systematic position as settled, until the larval characters are as well known as those of the adult.

6. Relative Importance of the Species.

It is difficult to give any satisfactory figure indicating the percentage of parasitism of the different species. Such figures, unless made from a large number of observations carried on over a long period, are apt to be very misleading. Another cause of uncertainty was the rather high mortality during the rearing work. With these reservations some figures obtained from rearing two large batches of insects in the incubator may be given. Since the two lots yielded approximately equal figures, they may be taken as a rough guide to the numerical status of the parasites in the field in early July 1928.

Total parasitism.			Percentage of hosts attacked by			
			<i>Orgilus obscurator</i>	<i>Cremastus interruptor</i>	<i>Omorgus mutabilis</i>	<i>Pimpla ruficollis</i>
Lot 1.	60 per cent.	...	36 per cent.	17 per cent.	3.6 per cent.	—
Lot 2.	56 per cent.	...	36 per cent.	8 per cent.	4.5 per cent.	5 per cent.

It was found that parasitism has a retarding effect on the development, consequently towards the end of the normal larval period of *buoliana* those insects which are still in the larval stage show a very high percentage of parasitism. Knowledge of this fact is of great assistance in sorting out material for shipment. The same phenomenon has already been observed by Pantel (1898) in the case of *Leptynia hispanica*, Bol., parasitised by the Tachinid, *Thrixion halidayanum*, Rond.

In order to obtain identification of material as early as possible, a large quantity of parasite larvae were isolated and placed in gelatin capsules in incubators at 80° F., as soon as they emerged from their hosts. Under these conditions it was found that the length of the pupal period was shortened by approximately one-third as the following table shows:—

Length of Pupal Stage	<i>Orgilus obscurator</i>	<i>Cremastus interruptor</i>	<i>Pimpla ruficollis</i>	<i>Pimpla examinators</i>
At room temperature ...	20 days	22 days	16-17 days	19 days
At 80° F.	13 days	14 days	11 days	13 days

7. Shipment to Canada.

The method of dealing with material intended for shipment was as follows:—Infested shoots, as they were sent in by the field collectors, were picked over by a gang of temporary workers. All the infested shoots were opened and the larvae, pupae, and parasite cocoons extracted. For the first shipment (12,000-15,000 larvae) pine-shoots were used for packing, these having first been sterilised in order to destroy any other insects which they might contain. Carbon tetrachloride, which was the substance first used for sterilisation, did not penetrate sufficiently even after 24 hours, and its use was therefore abandoned. Steam under pressure in an autoclave was, however, found to be effective. When the material had been thoroughly dried the larvae were packed in layers of shoots separated by brown paper, in small wooden boxes. Three of these boxes, each containing 4,000 or more larvae, were placed in a larger box, which was sent on 27th June in cold storage to Quebec, and from there at ordinary air temperature to the laboratory at Chatham, Ontario, where they were received on 9th July. On receipt the packing material was found to be very mouldy; but after a few experiments it was found that the larvae could be as successfully packed between layers of tissue paper as among sterilised pine-shoots, and this method was employed for the greater part of a second shipment. This shipment, which was of approximately the same size as the first, was sent on 5th July and was received by Mr. Baird on 16th July, who reported the emergence of parasites to be very satisfactory. He says: "The parasites on emergence were placed in cheese-cloth cages and were fed on sugar and water. *Cremastus* mated readily in the cages, but with *Orgilus* mating was not noted till after liberation."

The following species were represented in the material which was shipped:—*Cremastus interruptor*, Grav., *Orgilus obscurator*, Nees, *Omorgus mutabilis*, Holmg., *Pimpla examinators*, F., *Actia nudibasis*, Stein. Of these, specimens of the first three species, which appear to be dominant or key parasites in England, were liberated. As far as possible *Pimpla* spp. were excluded from the material shipped, and care was taken that none were liberated owing to the tendency of members of this genus to behave as hyperparasites under certain conditions. Particulars of liberation have been supplied by Mr. Baird as follows:—

"Colony sites for liberation of the parasites were chosen at Niagara Falls and Hamilton, Ontario. At Niagara Falls the flies were released in the Queen Victoria Park in a small group of pine trees close to the Refectory. The infestation in this park is rather light, but has persisted for some time, particularly in the larger trees,

which are difficult to clean up. Liberations were made at Hamilton in the Gage Memorial Park. There are several thousand young pine trees in this park and they are fairly heavily infested with *buoliana* in spite of the efforts of the superintendent to clean it up by cutting off and burning the infested shoots.

Details regarding the liberations, during July and August 1928, may be summarised as follows:—

	<i>Cremastus</i>	<i>Orgilus</i>	<i>Omorgus</i>	Total
Niagara Falls	120	19	0	139
Hamilton	547	664	17	1,228
Totals	667	683	17	1,367

In the following summer collections from these areas showed that the *Cremastus* and *Orgilus* had become established and had been able to pass the severe Canadian winter successfully."

8. Summary.

A preliminary study of the parasites of the Pine-shoot Moth, *Rhyacionia buoliana*, in England was undertaken at the request of the Dominion Entomologist of Canada.

In all twenty-eight species of primary and secondary parasites were obtained. Thirteen of these species were represented in our material by not more than two specimens and are probably of little economic importance. Of the remaining fifteen, two (*Habrocytus* and *Eulclius*) are definitely hyperparasites, and at least two of the Pimplines (*P. ruficollis* and *P. brevicornis*) are liable to live as hyperparasites under certain conditions.

The dominant or "key" parasites in this complex appear to be the Braconid, *Orgilus obscurator*, and two Ophionines, *Cremastus interruptor* and *Omorgus mutabilis*. These were shipped to Canada and the first two have become established there.

A brief account is given of the salient facts in the biology of each species and the more important diagnostic characters of the adults are described to facilitate accurate identification, often a very difficult matter.

The mature larvae of the commoner species are described in detail, with the particular object of finding satisfactory specific characters.

Of the common species the majority attack the larva. *Pimpla examinitor* is the only true pupal parasite which is at all common, but *Omorgus mutabilis* and *Orgilus obscurator*, although they are essentially larval parasites, frequently remain in their host and complete their development after it has pupated. Four other species, though normally living as larval parasites, may occasionally emerge from the pupa. One egg-parasite, *Trichogramma evanescens*, was recorded.

None of the common species is confined to *R. buoliana*, and there is no reason to suppose that the other species, about which less is known, are any more specific. Five of the species reared are new to Great Britain and eighteen constitute new records for this host.

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THE DISTRIBUTION OF TSETSE-FLIES IN THE SUDAN.

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(PLATES XIV-XVIII.)

Introduction.

In the Sudan, as in other parts of Africa, where tsetse-flies (*Glossina*) are known to occur, the distribution of the species is always a matter of considerable interest, owing to the fact that some are known to be disseminators of disease and others are suspected as being possible carriers. Of the twenty species so far recorded from the continent of Africa, nine have been experimentally proved to be capable of transmitting trypanosomes pathogenic to man or his domestic animals. As yet only five species have been found in the Sudan, namely, *G. palpalis fuscipes*, *G. morsitans*, *G. longipennis*, *G. fusca* and *G. fuscipleuris*, and of these the first four are known to be carriers of trypanosomiasis.

Until recently there has been no definite evidence that any species of *Glossina* occurs within Sudan territory to the east of the Nile north of latitude 6° N., although *G. morsitans* has on more than one occasion been taken at Gambeila (latitude 8° 15' N., longitude 34° 35' E.) in Abyssinia, 86 miles from the Sudan frontier. For some time rumours have been current that flies resembling *Glossina* have been observed in Fung Province along the Sudan-Abyssinian border, and a fly survey of this region has been planned by the Director of the Veterinary Department to be made during the coming rainy season, when the possibility of finding *Glossina* should, if it occurs, be greatest.

A New Locality for *Glossina palpalis fuscipes*.

In February of the present year definite information was received that tsetse-flies had been seen along the Khor Yabus in the south of Kurmuk District by Mr. T. D. Bayne, a Mining Engineer of Sir Robert Williams Company, London, who was at the time carrying out mining investigations in that district. As Mr. Bayne had had previous experience of tsetse-flies in Uganda, the Belgian Congo, and Rhodesia, there was little doubt felt that his observations were correct, and he was asked to do his utmost to obtain a specimen so that this interesting observation might be confirmed, and the species identified. One specimen was obtained after considerable trouble, which was despatched to Khartoum for determination and proved to be a male of *G. palpalis fuscipes*, its identification being confirmed by an examination of a microscope preparation of the male genitalia.

The few specimens seen were all observed within a short distance of Bilbibulo (longitude 34° 06' E., latitude 9° 58' N.), a small village situated on the north bank of Khor Yabus, approximately twelve miles due west from the Abyssinian frontier and four miles west of Abongoro. Khor Yabus is a small, swiftly running river, being at Bilbibulo approximately forty feet wide and with steep banks. It rises in the Shakodobi Hills in Abyssinia, whence it flows in a north-north-westerly direction until it crosses the Sudan-Abyssinian boundary at Wagalla (longitude 34° 14' E., latitude 9° 54' N.). From there its course runs for some distance due west and later flows south-west, being eventually lost in swamps at longitude 33° 30' E., latitude 9° 45' N., after traversing a distance of approximately sixty miles from the frontier. Khor Yabus has the distinctive feature of flowing throughout the year, which accounts for *G. palpalis* being found along its banks during the dry season, whereas other rivers and khors in the district are only in spate during and just after the rainy season, which lasts from May to September. Being well shaded by large trees and bushes the Yabus affords the kind of conditions most suited to *G. palpalis*. The country

to the north of the river is covered with bush and light forest interspersed by hills and low ridges of black igneous rocks, and to the south is a wide open expanse of typical cotton soil.

Although *G. palpalis* has only been seen for a short distance along the course of the Yabus, observations have been made only over a limited area and for the short period of one month. There would seem, however, every reason to believe that the fly frequents this river for a considerable distance, at any rate during some period of the year, although it is unlikely to penetrate further west into Abyssinia than the foot of the range of hills in which the river rises, and in the Sudan its distribution is undoubtedly limited by the swamps into which the Yabus finally flows.

A Suspected Region for *Glossina morsitans*.

Apart from the presence of *G. palpalis* along Khor Yabus there is strong evidence that another species of *Glossina*, probably *G. morsitans*, occurs during the rains in the country to the north of the Yabus extending along the Sudan-Abyssinian border to as far north as Gallabat or possibly further.

It is recorded by the Veterinary Department that trypanosomiasis is common among cattle in this region throughout the rainy season, and in years of very heavy rains it has been known to spread as far north as the Gedaref District. Captain J. Going, a Veterinary Inspector, made the interesting discovery that both *Trypanosoma vivax* and *T. congolense* occurred in the cattle of this region, a fact which makes one strongly suspect the presence of *G. morsitans*. Captain H. C. Brocklehurst, the Game Warden, who has had considerable experience in various parts of Africa where tsetse-fly is prevalent, states that he has actually caught specimens in the upper reaches of the River Dinder, but that they were unfortunately mislaid.

As yet no proper fly survey of this area has been carried out, partly owing to the great difficulty of transport during the rains and partly to the fact that such a survey at this period of the year would take much time; the proposal to do so this season is therefore viewed with considerable interest.

The Known Distribution of Tsetse-flies in the Sudan.

In order to illustrate the known distribution of the various species of *Glossina* which occur in the Sudan, copies of the map of the Sudan (scale 1 : 16,000,000) have been chosen on which have been delineated the demarcations and indices denoting the sheet-maps 1 : 1,000,000 and their sub-divisions 1 : 250,000, the latter being shaded in red according to the approximate distribution of each species. Such a method is not truly accurate, but is considered sufficiently so for the purpose. For instance, *G. palpalis* may be taken as occurring along all the rivers in a shaded square, while *G. morsitans* will be found in the forests and bush country between such rivers. The following brief description of the distribution of species should be consulted in conjunction with the maps given at the end of this paper.

Glossina palpalis fuscipes, Newst.

This fly is chiefly to be found to the west of the Nile extending in a diagonal belt from latitude 9° 10' N., in the north-west of the Bahr el Ghazal Province, in a south-easterly direction through the western and southern districts of the latter province and southern Mongalla Province. To the east of the Nile it is found in a narrow belt along the southern boundary of Mongalla Province on the border of Uganda, where it chiefly inhabits the Nile Valley. As will be seen on reference to the map showing its distribution, its occurrence along Khor Yabus is considerably isolated from the belt referred to above.

It is considered worthy of note that all male specimens of this tsetse-fly taken in the Sudan, which have been dissected for examination of their genitalia, have been

found to conform to the eastern form of *G. palpalis*, namely subspecies *fuscipes*. Newstead. During the rainy season of 1918 the writer made a tour of the Yei District in south-west Mongalla Province with a view to ascertaining whether any true *palpalis* occurred in that district. Of the 1,262 specimens captured, 499 were males. From the latter, 92 slides of male genitalia were prepared, and all were found to belong to the subspecies *fuscipes*. Later examinations of male genitalia of specimens taken in other districts have produced similar results.

Glossina morsitans, Westw.

The general distribution of *G. morsitans* in the Sudan very closely follows that of the previous species, with the exception of an isolated belt in the Koalib Hills in Kordofan Province on the west of the Nile, which lies between longitude 30° 15' and 30° 30' E., and latitude 11° 30' and 12° N. The extent of this belt is twenty miles long from north to south and three miles from east to west at the widest point. The possibility of this species being found during the rainy season along the Sudan-Abyssinian boundary has already been mentioned.

By examinations of the male genitalia of large numbers of specimens of this fly it has been shown that only the eastern form of *G. morsitans* occurs in the Sudan.

Glossina fusca, Walk.

This species has been taken along the Yubo River in the Tembura District in the south of Bahr el Ghazal Province. It is possible that it is more widely distributed in the latter province than our present records show.

Glossina fuscipleuris, Aust.

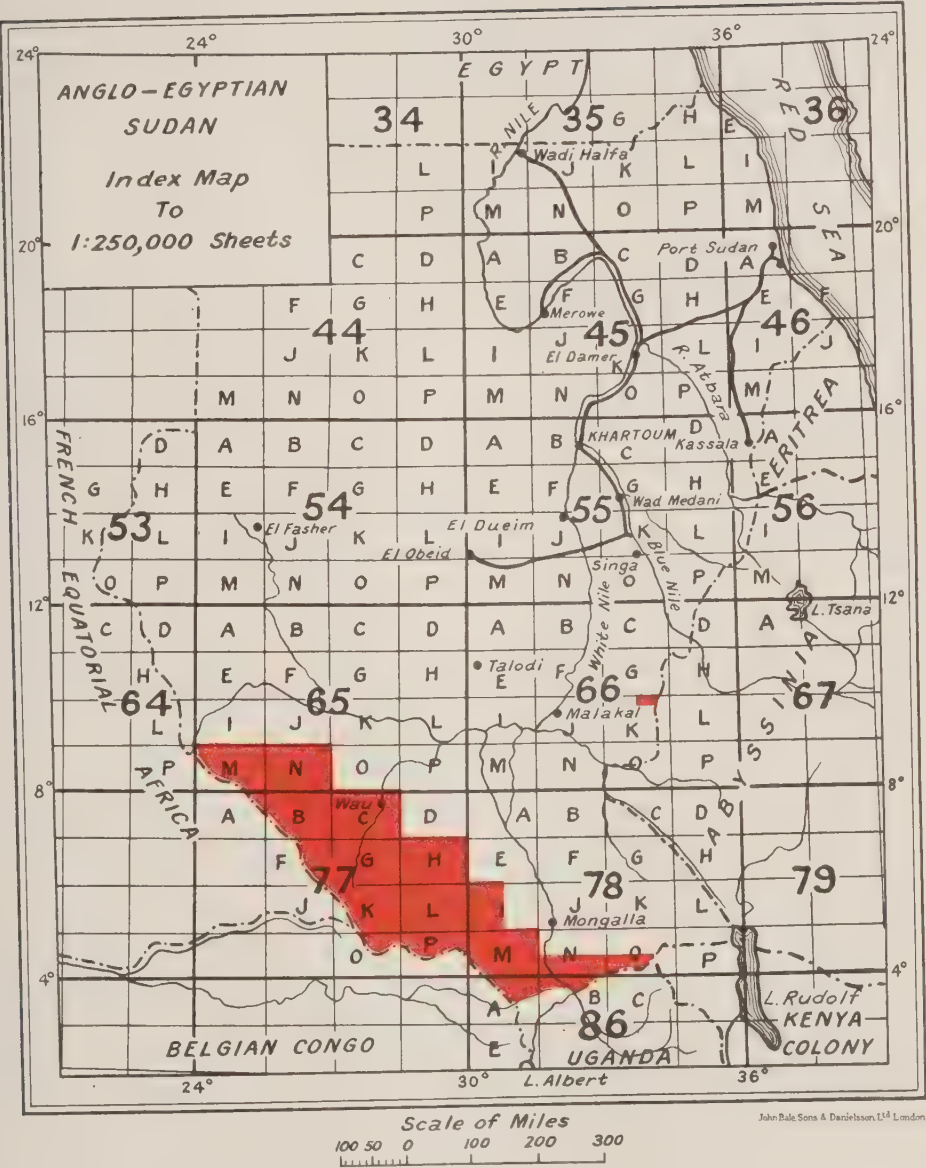
Specimens of this fly have been taken in the Tembura District along with *G. fusca*, and also in the Meridi District to the south.

Glossina longipennis, Corti.

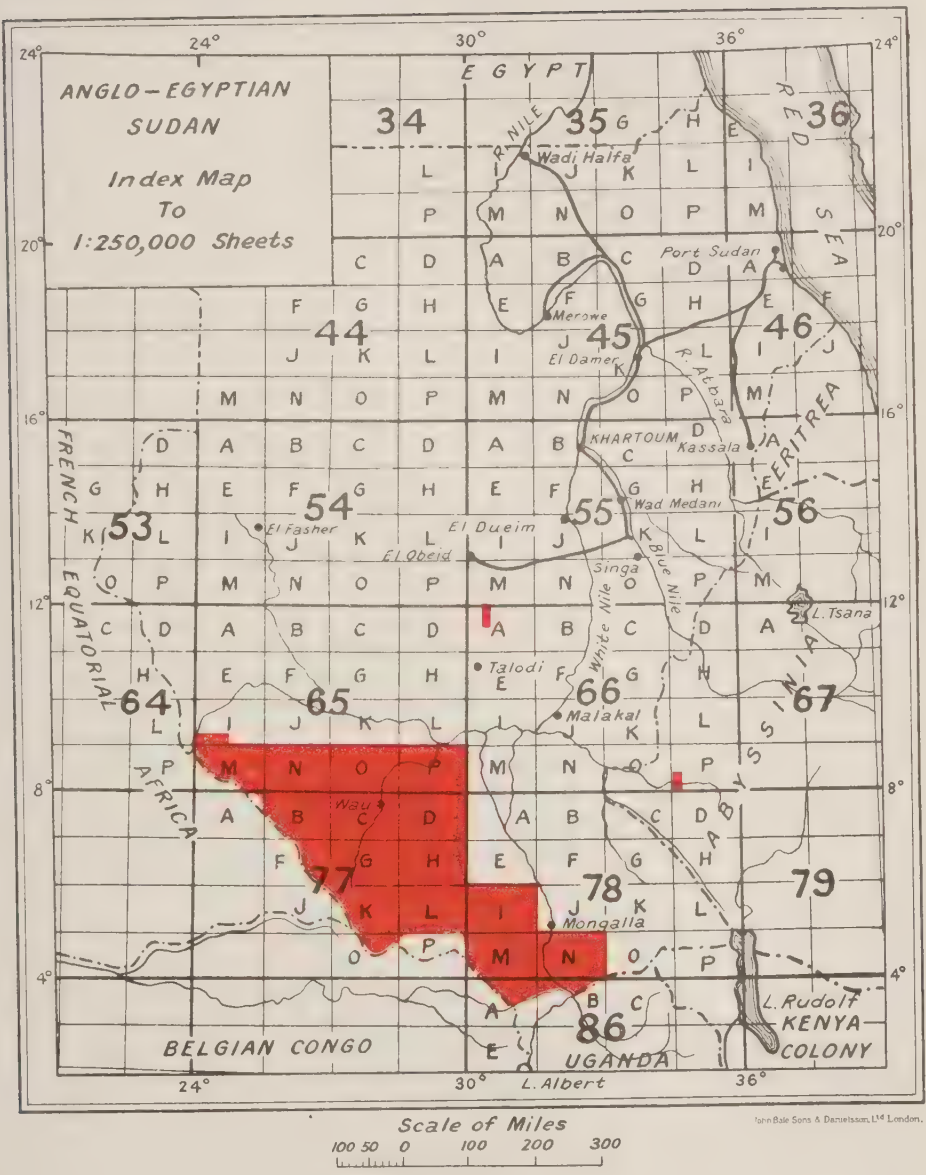
Recorded in 1913 as occurring in Mongalla Province to the east of the Nile, at two localities situated at longitude 33° 18' E., latitude 4° 30' N., and longitude 34° 36' E., latitude 5° 55' N.

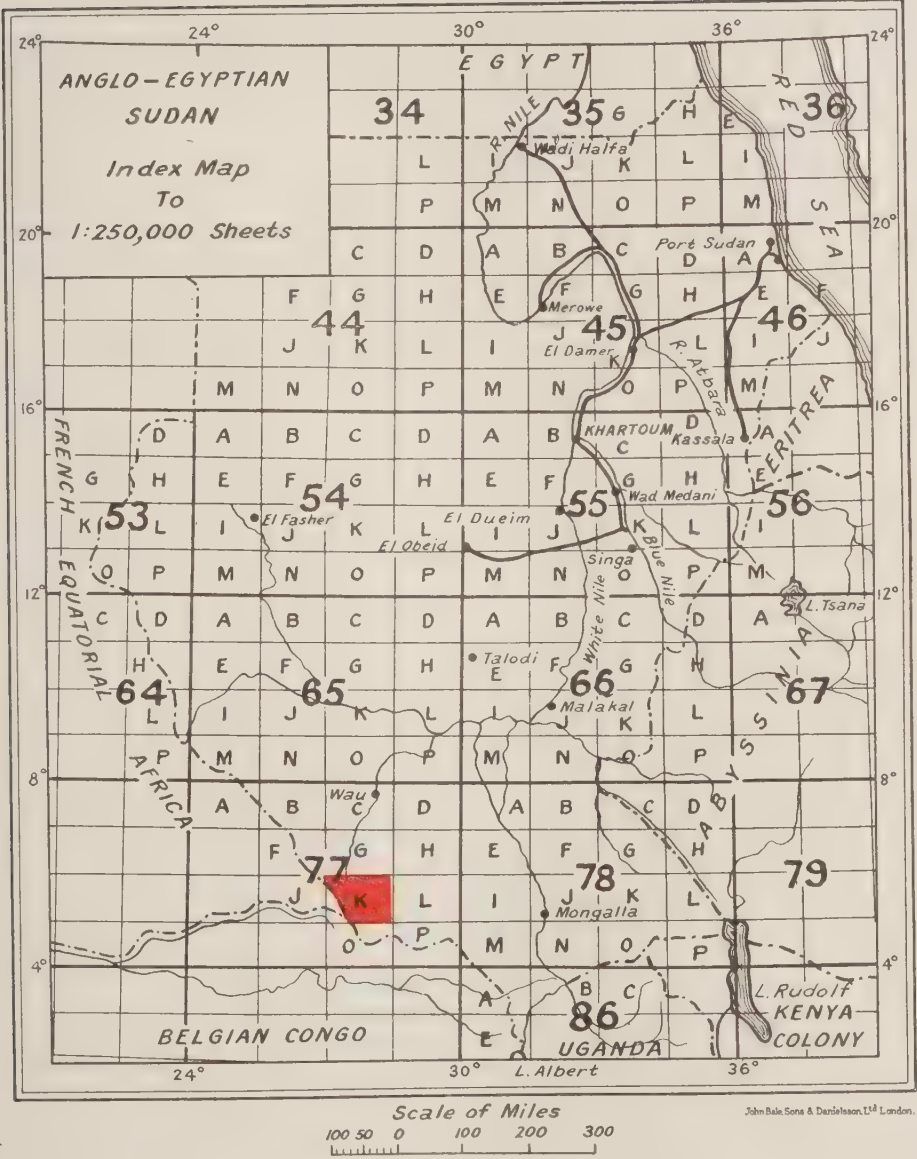
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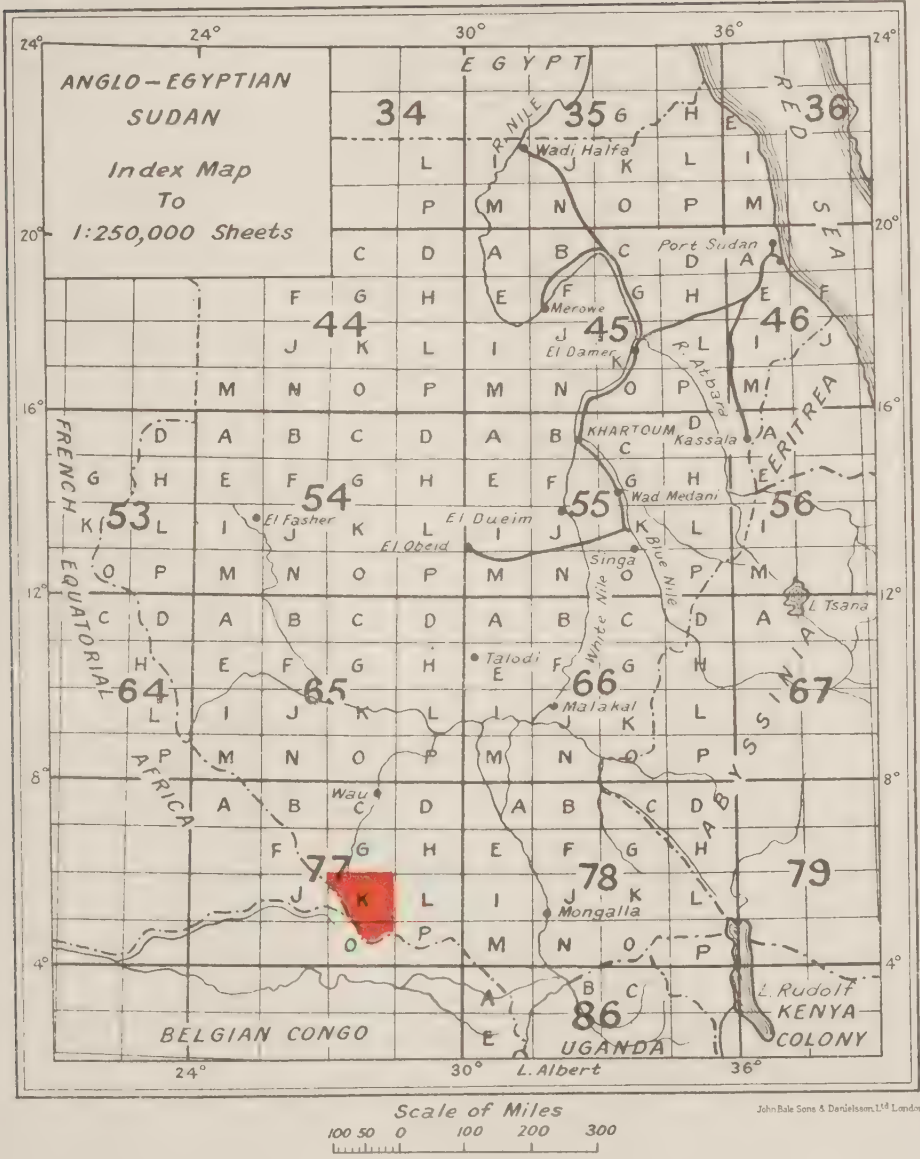


Approximate distribution in the Sudan of
Glossina palpalis fuscipes, Newst.





Approximate distribution in the Sudan of
Glossina fusca, Walk.



Approximate distribution in the Sudan of
Glossina fuscipleuris, Aust.



John Bale, Sons & Danielsson, Ltd London.

Approximate distribution in the Sudan of
Glossina longipennis, Corti.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st April to 30th June, 1930, and the thanks of the Managing Committee are tendered to the contributors for their kind assistance:—

Mr. W. ALLAN :—2 Hippoboscidae, 4 other Diptera, 147 Coleoptera, 4 Rhynchota, and 34 Orthoptera ; from Northern Rhodesia.

Mr. T. J. ANDERSON, Government Entomologist :—11 Diptera, 59 Coleoptera, 172 Lepidoptera, 3 species of Coccidae, 6 other Rhynchota, and 10 Orthoptera ; from Kenya Colony.

Mr. A. G. BENNETT :—26 Diptera, and 8 Coleoptera ; from the Falkland Islands.

Dr. G. BONDAR :—102 Coleoptera ; from Brazil.

Mr. H. E. BOX :—85 Diptera, 594 Coleoptera, 768 Hymenoptera, 49 Lepidoptera, 14 early stages, and 3 slides of genitalia, 341 Rhynchota, 4 Isoptera, 98 Orthoptera, and 11 Planipennia ; from South America.

Prof. W. H. BRITAIN :—274 Hymenoptera and 25 microscope slides of Aphidae ; from Canada.

Mr. L. L. BUCHANAN :—7 Curculionidae ; from the Argentine.

Dr. P. A. BUXTON, London School of Tropical Medicine :—27 Tabanidae, 16 *Lyperosia*, 8 other Diptera, 27 Coleoptera, 13 Rhynchota, and 2 Orthoptera ; from various localities.

Dr. A. CHIAROMONTE :—21 Coleoptera, 3 Parasitic Hymenoptera, 4 Lepidopterous larvae, and 7 Orthoptera ; from Eritrea.

Dr. R. N. CHRYSTAL :—2 Coleoptera ; from the Gold Coast.

Mr. A. T. CLARK :—3 Scolytidae ; from New Zealand.

Mr. L. D. CLEARE, Junr., Government Entomologist :—5 Tabanidae, 6 other Diptera, 46 Coleoptera and 6 early stages, 3 Parasitic Hymenoptera, 2 Formicidae, 45 Lepidoptera, 2 Cimicidae, 1 species of Aphidae, 1 species of Coccidae, 6 other Rhynchota, 10 Orthoptera, 2 Millipedes, 20 Woodlice, 2 Parasitic Worms, 4 Leaches, and 4 Snail shells ; from British Guiana.

Prof. T. D. A. COCKERELL :—17 Diptera, 2 Coleoptera, 24 Parasitic Hymenoptera, 42 other Hymenoptera, 24 Lepidoptera, 7 Thysanoptera, 9 Rhynchota, 7 Orthoptera, 3 Odonata, and 6 Collembola ; from various localities.

THE CONSUL-GENERAL, ALGIERS :—22 Orthoptera ; from Algeria.

THE CONSUL-GENERAL, TUNIS :—3 Orthoptera ; from Tunisia.

Mr. W. COOK :—373 Orthoptera ; from the Gold Coast.

Mr. G. H. CORBETT, Government Entomologist :—47 Diptera, 81 Coleoptera, 82 Parasitic Hymenoptera, 41 Formicidae, 93 Lepidoptera, 50 Isoptera, 10 Thysanoptera, 2 species of Aphidae, 21 species of Coccidae, 131 other Rhynchota, and 5 Orthoptera ; from the Federated Malay States.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—3 Tabanidae, 2 Nycteribiidae, 125 other Diptera, 109 Hymenoptera, 3 Ephemeridae, and 2 Planipennia ; from Kenya Colony.

Mr. A. CUTHBERTSON, Assistant Entomologist :—13 Diptera, 6 Coleoptera, 3 Parasitic Hymenoptera, and 2 other Hymenoptera ; from Southern Rhodesia.

Mr. D. d'EMMERZ DE CHARMOY :—220 Parasitic Hymenoptera and 4 Gryllidae ; from Mauritius.

THE DIRECTOR, EAST AFRICAN RESEARCH STATION, AMANI :—8 Coleoptera ; from Tanganyika Territory.

DIRECTOR OF RESEARCH, BAGHDAD :—8 Parasitic Hymenoptera ; from Iraq.

DIRECTOR OF VETERINARY SERVICES, PRETORIA :—4 tubes containing a large number of Mites ; from South Africa.

Mr. R. DU PASQUIER :—10 Chalcididae ; from French Indo-China.

Mr. P. R. DUPONT :—100 Coleoptera and early stages ; from Seychelles.

Dr. H. S. EVANS :—14 Culicidae, 18 Tabanidae, 10 other Diptera, 200 Coleoptera, 600 Hymenoptera, 30 Lepidoptera, 2 Coccidae, 6 other Rhynchota, 10 Orthoptera, 4 Isoptera, and 2 Odonata ; from the Congo-Rhodesian Border.

Brig.-Gen. W. H. EVANS :—24 Coleoptera, 8 Rhynchota and 3 early stages and 36 Orthoptera ; from Quetta, India.

Mr. T. BAINBRIDGE FLETCHER, Imperial Entomologist :—10 Parasitic Hymenoptera ; from India.

Mr. C. FRANSSEN :—23 Coleoptera, 42 Parasitic Hymenoptera, and 29 Lepidoptera ; from Java.

Mr. J. C. M. GARDNER, Systematic Entomologist :—84 Coleoptera and 122 Parasitic Hymenoptera ; from Dehra Dun, India.

Dr. CL. GAUTIER :—11 Parasitic Hymenoptera ; from France.

Mr. P. V. D. GOOT :—59 Lepidoptera ; from Java.

Miss LILIAN GRAHAM :—21 Parasitic Hymenoptera ; from Canberra City, F.C.T., Australia.

Mr. W. GREENWOOD :—18 Coleoptera, 11 Moths, and 4 Orthoptera ; from the Fiji Islands.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—7 Tabanidae, 24 *Stomoxys*, 26 other Diptera, 170 Coleoptera, 2,034 Parasitic Hymenoptera, 310 other Hymenoptera, 239 Lepidoptera and 11 cocoons, 2 species of Coccidae, 329 other Rhynchota, 13 Orthoptera, 3,000 Collembola, 100 Mites, and 10 Chelifers ; from Uganda.

Mr. G. H. HARDY :—16 Diptera ; from Queensland.

Mr. E. HARGREAVES, Government Entomologist :—24 Culicidae, 2 *Tabanus*, 11 other Diptera, 105 Coleoptera, 4 Parasitic Hymenoptera, 60 other Hymenoptera, 84 Lepidoptera, 3 species of Coccidae, 14 other Rhynchota, 155 Orthoptera, 5 larvae, and 40 egg masses, 4 Planipennia, 11 Trichoptera, 2 Ephemeridae, 7 Scorpions, and 5,000 Mites ; from Sierra Leone.

Mr. W. W. HENDERSON :—13 Orthoptera ; from Northern Nigeria.

Mr. G. M. HENRY, Colombo Museum :—245 Coleoptera and 85 Rhynchota ; from Ceylon.

Dr. F. G. HOLDAWAY :—3 Diptera, 33 Coleoptera, and 4 Parasitic Hymenoptera ; from France.

Mr. G. H. E. HOPKINS, Medical Entomologist :—2,220 Culicidae, 948 Coleoptera, and 733 Rhynchota ; from Uganda.

Mr. G. V. HUDSON :—55 Coleoptera ; from New Zealand.

Mr. R. W. JACK, Chief Entomologist :—4 Orthoptera ; from Southern Rhodesia.

Mr. J. T. KENNEDY :—7 Tabanidae and 602 *Glossina* ; from Uganda.

Mr. R. H. LE PELLEY :—11 Rhynchota ; from Kenya Colony.

Dr. S. LEEFMANS :—3 Coleoptera ; from Java.

LEICESTER MUSEUM AND ART GALLERY :—20 Psychodidae ; from Leicester.

Mr. C. L. LENG :—1 Weevil ; from Porto Rico.

Mr. G. A. MAVROMOUSTAKIS :—5 Orthoptera ; from Cyprus.

Dr. D. MILLER, Chief, Department of Entomology, Cawthron Institute :—370 Coleoptera and 13 early stages, 218 Parasitic Hymenoptera, 20 other Hymenoptera, and 100 Mites ; from New Zealand.

Mrs. MOISER :—1 Mantid ; from Southern Rhodesia.

Mr. H. M. MORRIS, Government Entomologist :—56 Dipterous larvae ; from Cyprus.

Mr. J. MUGGERIDGE :—28 Diptera, 15 Coleoptera, 4 Hymenoptera, 60 Collembola, and 100 Thysanoptera ; from New Zealand.

MUSEE ROYAL D'HISTOIRE NATURELLE, BRUXELLES :—555 Curculionidae ; from the Dutch East Indies.

Dr. J. G. MYERS :—2 Siphonaptera, 2 Culicidae, 80 other Diptera, 248 Coleoptera and 4 larvae, 674 Parasitic Hymenoptera, 20 Formicidae, 11 other Hymenoptera,

99 Lepidoptera, 1 species of Aphidae, 4 species of Coccidae, 69 other Rhynchota, 9 Orthoptera, and 150 Spiders; from Trinidad.

NATAL MUSEUM, PIETERMARITZBURG :—114 Orthoptera; from South Africa.

Mr. A. PICKLES :—2 Diptera and 90 Rhynchota; from Trinidad and Jamaica.

Mr. Y. RAMACHANDRA RAO, Government Entomologist :—2 Coleoptera and 6 Rhynchota; from South India.

Dr. P. R. REGNIER :—5,000 Orthoptera; from Morocco.

Mr. A. H. RITCHIE, Government Entomologist :—18 Diptera, 36 Coleoptera, 76 Parasitic Hymenoptera, 2 other Hymenoptera, and 10 Orthoptera; from Tanganyika Territory.

Dr. W. ROEPKE :—4 Hymenoptera, 105 Lepidoptera, and 2 Rhynchota; from Java.

Dr. H. SACHTLEBEN :—7 Parasitic Hymenoptera; from Germany.

Dr. H. SCHOUTEDEN, MUSEE DU CONGO BELGE :—11 Diptera; from the Belgian Congo.

Mr. H. W. SIMMONDS :—3 *Tabanus*, 35 other Diptera, 20 Coleoptera, 19 Parasitic Hymenoptera, 6 other Hymenoptera, 25 Lepidoptera, 30 Rhynchota, and 2 Orthoptera; from Trinidad.

Mr. C. SMEE, Government Entomologist :—200 Chalcididae, 1 species of Aleurodidae, 6 species of Aphidae, 6 species of Coccidae, 18 other Rhynchota, 150 Thysanoptera, and 100 Mites; from Nyasaland.

Mr. B. SOKANOWSKI :—110 Parasitic Hymenoptera; from Russia.

Mr. M. SUREYA :—81 Diptera; from Ayintape, Turkey.

Mr. F. W. URICH :—27 Coleoptera and 2 slides of genitalia; from Trinidad.

Mr. R. N. WADSWORTH :—10 Dipterous early stages; from Birmingham.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—2 *Tabanus*, 5 *Stomoxys*, 116 other Diptera, 109 Coleoptera, 164 Parasitic Hymenoptera, 245 other Hymenoptera, and 135 Rhynchota; from the Sudan.

Mr. D. S. WILKINSON :—13 Diptera, 54 Coleoptera, 4 Hymenoptera, 6 Rhynchota, and 931 Orthoptera; from Tunisia.

VARIATIONS IN THE WING ORNAMENTATION OF *ANOPHELES FUNESTUS*, GILES.

By H. S. LEESON, F.E.S., A.R.San.I.,
London School of Hygiene and Tropical Medicine.

It is well known that *Anopheles funestus*, Giles, the common African mosquito, is an exceedingly variable species, especially in the ornamentation of the wings. The arrangement of the pale and dark wing-scales varies so much in different individuals that doubt is apt to arise as to whether the specimens have been correctly identified. A preliminary examination of a large amount of material collected in Southern Rhodesia showed that the specimens could easily be separated into ten groups; basing the distinctions upon the arrangement of the scales on the costa and first longitudinal vein. As this species is an important vector of malaria it seemed desirable that these variations in wing markings should be studied in detail, and an attempt made to find an explanation for them.

On returning to England a random selection consisting of 1,084 specimens of both sexes was taken from the collection. Each insect was then examined under a low power binocular microscope and according to the scaling of the costa and first



Fig. 1. Ornamentation of costa and first longitudinal vein of *Anopheles funestus*, Giles, showing positions of dark and pale spots.

longitudinal vein was placed in its appropriate group. Nine of the groups observed in Southern Rhodesia were present in this selection; one, Group VII, was not represented.

The markings on the wings upon which the separation into groups was based are indicated in fig. 1. For the sake of brevity it was found convenient to employ the following symbols: D_1 , D_2 , D_3 , D_4 , for the dark spots, and P_1 , P_2 , P_3 , P_4 , for the pale spots, counting outwards from the base of the wing. The manner in which the wings of each group differ is described below and the number of specimens falling into the groups is also given. Fig. 2 will assist in following the descriptions.

Group I (fig. 2). 120 specimens.

On the costa, D_1 occupied approximately the basal third and was separated from D_2 by P_1 . D_2 , D_3 and D_4 were each smaller than D_1 and decreased in length successively.

On the subcosta, D_1 was situated under the distal portion of D_1 costa and rather less than half its length. D_2 was immediately under, and of the same length as, D_2 costa.

On the first longitudinal vein, D_1 was situated immediately below D_1 subcosta and of the same length. D_2 was below the distal part of D_2 subcosta, but only two-thirds of its length. The proximal third of this area was pale and continuous

with P_1 , that is, the accessory spot was absent. D_3 and D_4 were below D_3 and D_4 costa respectively.

Group II (fig. 2). 14 specimens.

In this wing, D_3 and D_4 were joined on the costa and on the first longitudinal vein, so that P_3 was absent from each vein. The accessory spot was present.

Group III (fig. 2). 16 specimens.

D_2 and D_3 were continuous on the first longitudinal vein, obliterating P_2 on that vein. The accessory spot was present.

Group IV (fig. 2). 32 specimens.

On the costa, D_1 and D_2 were joined, so that P_1 was absent, though present on the subcosta and the first longitudinal vein. The accessory spot was present.

Group V (fig. 2). 896 specimens.

The arrangement of the scales on the costa, subcosta and first longitudinal vein in this group were exactly as in Group I, with the addition of the accessory spot on the first longitudinal vein.

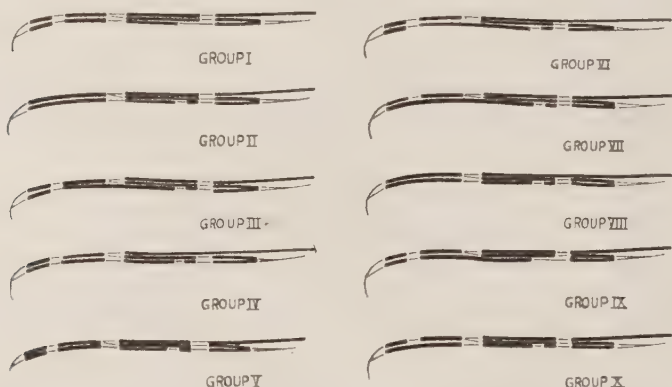


Fig. 2. Ornamentation of costa and first longitudinal vein of *Anopheles funestus*, Giles.

Group VI (fig. 2). 1 specimen.

D_1 and D_2 costa were joined, crossing P_1 costa; also D_2 and D_3 on the first longitudinal were joined, abolishing P_2 on that vein. The accessory spot was present.

Group VII (fig. 2). None.

P_2 and P_3 on the first longitudinal were both absent, caused by the continuation of D_2 , D_3 and D_4 on that vein. The accessory spot was present.

This type of wing was observed in a preliminary examination made in Southern Rhodesia, but no examples were present in the material now being discussed.

Group VIII (fig. 2). 1 specimen.

D_1 and D_2 costa were united across P_1 ; also D_3 and D_4 on both costa and first longitudinal were joined, so that P_3 was absent from both veins. The accessory spot was present.

Group IX (fig. 2). 2 specimens.

D_2 and D_3 on the first longitudinal vein were joined across P_2 and the accessory spot was absent.

Group X (fig. 2). 2 specimens.

D₃ on the first longitudinal vein was continuous with D₄, thus obliterating P₃ on that vein. The accessory spot was present.

TABLE I.

Analysis of the Ornamentation of the Costa and First Longitudinal Vein of 1,084 Specimens of Anopheles funestus.

Group.	Vein.	D ₁	D ₂	D ₃	D ₄	P ₁	P ₂	P ₃	P ₄	Access spot.	No. in group.
I ...	Costa ... 1st L. Vein ...	+	+	+	+	+	+	+	+	—	120
II ...	Costa ... 1st L. Vein ...	+	+	←—	—→	+	+	—	+	+	14
III ...	Costa ... 1st L. Vein ...	+	+	+	+	+	+	+	+	+	16
IV ...	Costa ... 1st L. Vein ...	←—	—→	+	+	—	+	+	+	+	32
V ...	Costa ... 1st L. Vein ...	+	+	+	+	+	+	+	+	+	896
VI ...	Costa ... 1st L. Vein ...	←—	—→	+	+	—	+	+	+	+	1
VII ...	Costa ... 1st L. Vein ...	+	+	+	+	+	+	+	+	+	6
VIII ...	Costa ... 1st L. Vein ...	←—	—→	←—	—→	—	+	—	+	+	1
IX ...	Costa ... 1st L. Vein ...	+	+	+	+	+	+	+	+	—	2
X ...	Costa ... 1st L. Vein ...	+	+	+	+	+	+	+	+	+	2

Notes.

D₁, D₂, D₃, D₄, indicate dark spots or markings.

P₁, P₂, P₃, P₄, indicate pale spots or markings.

+ indicates marking present and normal.

— indicates marking absent.

←—→ indicates two or more dark markings joined together.

Details of the wing markings are analysed in Table I. By comparing this table with the illustrations the following facts become evident :—

1. The accessory spot was absent from only two groups, I and IX.
2. Other dark spots were not reduced in any way. [Evans (1927), Plate ii, fig. 5, shows D₁ costa interrupted.]
3. On the contrary, dark areas were frequently extended, thus obliterating one or more pale spots.
4. The following were constant :—
(a) D₁ and D₂ on the subcosta ; (b) D₁ on the first longitudinal vein ; (c) P₁ on the first longitudinal vein ; (d) P₂ on the costa.
5. Group V comprised nearly nine-tenths of the whole sample.

As the individuals placed in Group V were so numerous, a further examination was undertaken. It was then found that the specimens could easily be divided into three sub-groups according to the amount of dark scales on the third longitudinal vein ; these sub-groups will be referred to as Va, Vb and Vc (fig. 3).

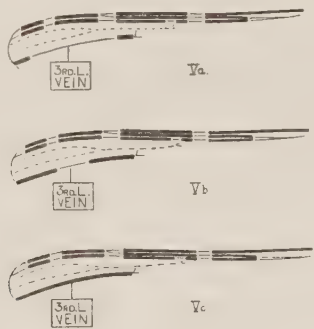


Fig. 3. Ornamentation of the third longitudinal vein in the three forms of *Anopheles funestus*, Giles, Group V.

In Group Va the third vein was mostly pale except for a dark spot at each extremity ; 594 specimens belonged to this group, approximately 66 per cent.

In Group Vb the third vein was mostly dark except for the centre third or less, which was pale ; 158 specimens belonged to this group, approximately 18 per cent.

In Group Vc the whole of the third vein was completely dark ; 144 specimens belong to this group, approximately 16 per cent.

TABLE II.
Numbers of Anopheles funestus, Group V, distributed according to Sex, Habitat and Month of Capture.

Wet Season.								Dry Season.					Totals	
Oct.Nov.Dec. Jan. Feb. Mar. Apr.								May	June	July	Aug.	Sep.		
Inside	a	1	1	—	11	50	50	32	5	—	—	4	2	156
	+	—	—	—	8	9	8	2	2	—	—	—	—	29
	b	—	—	—	1	3	2	2	2	1	—	1	—	12
	+	1	—	—	8	9	10	2	2	—	—	—	—	32
c	+	—	—	—	—	—	3	2	1	1	1	—	—	8
	+	3	—	—	2	4	12	1	3	1	2	3	1	32
Totals		5	1	—	30	75	85	41	15	3	3	8	3	269
Outside	a	4	2	—	11	218	58	26	5	2	1	5	—	332
	+	—	—	—	5	52	12	7	1	—	—	—	—	77
	b	1	—	—	1	8	—	—	2	2	—	3	—	17
	+	1	—	—	10	56	25	1	2	—	1	1	—	97
	c	—	—	—	1	—	1	—	16	12	4	3	—	37
	+	1	—	—	—	16	7	1	13	11	3	15	—	67
Totals		7	2	—	28	350	103	35	39	27	9	27	—	627

An attempt was then made to discover if these differences in pattern could be attributed to sex, habitat or season. The numbers of specimens are given in Table II in their relation to these factors.

1. *Sex.*

In Group V there were 562 males and 334 females distributed as follows :—

		<i>Males.</i>	<i>Females.</i>
Va	... ..	488 = 87 per cent.	106 = 32 per cent.
Vb	... ..	29 = 5 per cent.	129 = 38 per cent.
Vc	... ..	45 = 8 per cent.	99 = 30 per cent.
		562 = 100 per cent.	334 = 100 per cent.

From these figures it will be seen that the majority of males were of the pale form (Va) while the intermediate and dark forms only accounted for 13 per cent. between them. The females were more evenly divided.

Taking the number of individuals of each form as the base, the percentages would be :—

		<i>Males.</i>	<i>Females.</i>
Va	... ..	80 per cent.	20 per cent. = 100 per cent.
Vb	... ..	18 per cent.	82 per cent. = 100 per cent.
Vc	... ..	31 per cent.	69 per cent. = 100 per cent.

By this method of reckoning, it appears that the majority of the pale form were males and that the majority of the intermediate and dark forms were females ; but as the variations are not characteristic features of one sex they cannot be held to be related to this factor alone.

2. *Habitat.*

An analysis of the sites of capture of those individuals falling into this group shows that 627 were taken out of doors and 269 inside dwellings, approximately 70 per cent. and 30 per cent. respectively. The percentages of the forms found in each type of habitat are as follows :—

		<i>Inside.</i>	<i>Outside.</i>
Va	... ..	185 = 68 per cent.	409 = 65 per cent.
Vb	... ..	44 = 16 per cent.	114 = 18 per cent.
Vc	... ..	40 = 16 per cent.	104 = 17 per cent.
		269 = 100 per cent.	627 = 100 per cent.

On account of the larger numbers in Va, the pale form naturally predominates in both situations, and in reckoning the percentages independently for each form it is found that in each case the figures for outside habitats are considerably larger than those for the indoor situations. This was also partly to be expected, but the remarkable similarity between the figures for each form would seem to indicate that the ornamentation of the wing is in no way related to habitat.

		<i>Inside.</i>	<i>Outside.</i>
Va	... ..	31 per cent.	69 per cent. = 100 per cent.
Vb	... ..	28 per cent.	72 per cent. = 100 per cent.
Vc	... ..	28 per cent.	72 per cent. = 100 per cent.

The seasonal factor must now be considered.

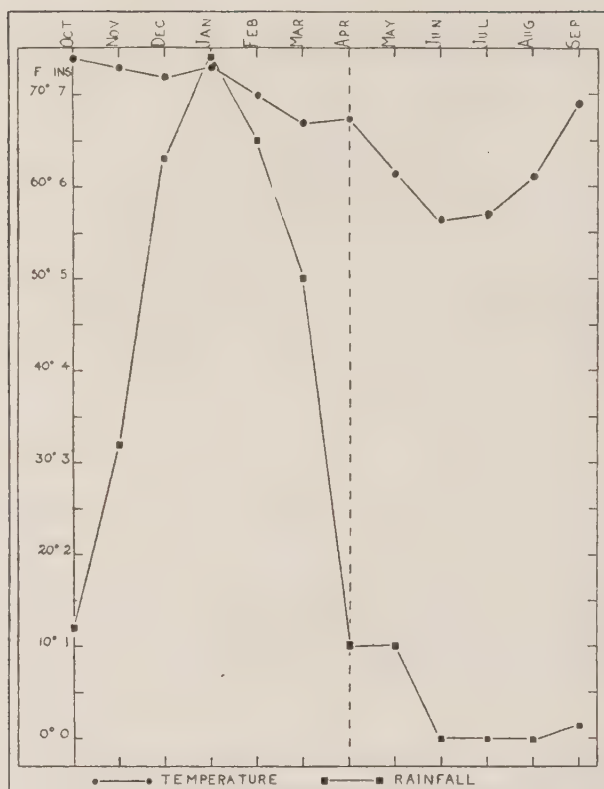


Fig. 4. Typical average monthly temperature and rainfall in Southern Rhodesia. The records were taken from stations of more than five years duration; the temperatures for the year ended 30th June 1927, and the rainfall for the period of the stations' existence up to the same date.

3. Season.

In Southern Rhodesia the climatic year is divided most definitely into two seasons, wet and dry. The rains commence in October and cease in April; May to September are dry months. In fig. 4 it will be observed that the temperature is highest in the wet season and lowest in the dry season. The graph is compiled from data supplied up to 30th June 1927, and represents the average monthly temperature and rainfall at five stations which have been in existence over five years. The stations were Salisbury, Bulawayo, Umtali, Gatooma and Shamva, and the figures were extracted from the Annual Meteorological Report, Department of Agriculture, Southern Rhodesia, 1928.

In the wet season (October to April) 762 specimens were captured and in the dry season (May to September) 134. Among the groups the figures were distributed as follows:—

			Wet Season.		Dry Season.	
Va	...	...	567	= 74 per cent.	27	= 20 per cent.
Vb	...	...	141	= 18 per cent.	17	= 13 per cent.
Vc	...	...	54	= 8 per cent.	90	= 67 per cent.
			762	= 100 per cent.	134	= 100 per cent.

Of the wet season captures the largest percentage consisted of pale forms (Va), while in the dry season dark forms (Vc) prevail. Within the forms themselves the percentages work out as :—

		Wet Season.	Dry Season.
Va	... ..	95 per cent.	5 per cent. = 100 per cent.
Vb	... ..	89 per cent.	11 per cent. = 100 per cent.
Vc	... ..	37 per cent.	63 per cent. = 100 per cent.

Thus it is shown that most of the pale and intermediate forms were collected in the wet season, whereas nearly two-thirds of the dark forms were collected in the dry season. The percentages for each group are graphed in fig. 5, where it is seen that

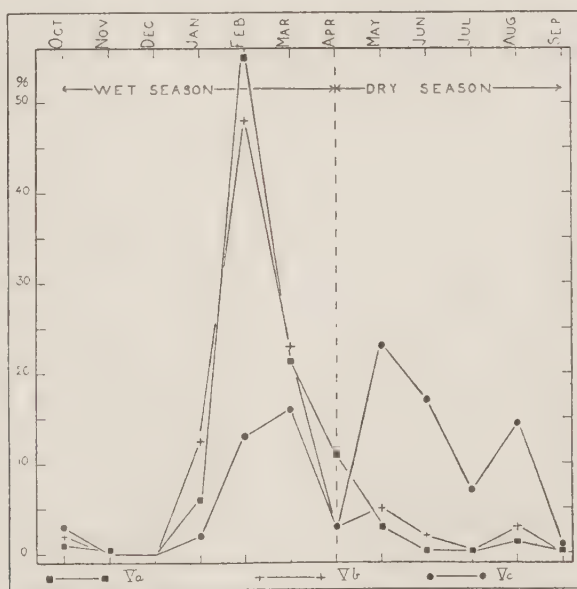


Fig. 5. Seasonal distribution in Southern Rhodesia of the three forms of *Anopheles funestus* in Group V; the percentages are reckoned independently for each form.

Va and Vb reached their maximum prevalence in February and Vc in May. This may be stated simply, by saying that pale forms predominate in the wet season and dark forms in the dry season.*

If figs. 4 and 5 are compared, it appears that Va and Vb do not increase in numbers during a period of high temperature unless accompanied by a simultaneous heavy rainfall, for with a combined drop in temperature and the amount of rain, they began to disappear. There were only 144 individuals in Group Vc, but it is perhaps worthy of note that this form appeared to be more responsive to temperature changes than to variations in the rainfall.

* The conclusion that pale forms occur in the wet season is borne out by the fact that of the remaining 188 specimens belonging to Groups I to IV and VI to X, 120 occurred in Group I; these were pale forms and reached their maximum prevalence in February, the height of the wet season. There were not enough in the other groups to enable any conclusions to be drawn.

In his paper on the *Nyssorhynchus* group of *Anopheles*, Davis (1928) comes to the following conclusion:—

“It is suggested that melanism is not only correlated with progressing distance from the equator (Root) but with the seasons, being more marked during the colder months of the year.”

The present observations on *Anopheles funestus* certainly appear to corroborate the latter part of this suggestion, and it would therefore seem that the dark or light forms of this species are not so much related to sex or habitat as to season and temperature.

In view of this conclusion, it would be of considerable interest to elucidate if the dark form is the one which carries the species through the cold months (May to September) to the next season of high temperature. Unfortunately in the present instance, so many females collected from hibernating places were dissected that, although the general impression is that they were of the dark form, no definite statement can be made. It may also be possible to establish whether the dark or pale form is the chief transmitter of malaria or whether both are equally implicated. During recent investigations in Southern Rhodesia, no record was kept as to whether infected females were of the dark or pale form.

It is suggested that it would be extremely helpful if, in future work, these details of wing ornamentation were recorded.

Summary.

1. The ornamentation of the wings in *Anopheles funestus*, Giles, is variable.
2. Nine distinct arrangements of the wing scales were observed in a random sample of 1,084 individuals.
3. Nearly nine-tenths of the specimens occurred in one group, in which there were dark and pale forms.
4. Variations in wing markings are not solely related to sex or to habitat.
5. The pale form was more prevalent in the wet season and the dark form in the dry season.
6. It is suggested that further study may reveal whether the dark form is the hibernating variety and whether one form is more important as a carrier of malaria than the other, and that these details of wing ornamentation should be recorded in future.

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A SIMPLE METHOD OF MAKING PERMANENT MICROSCOPE MOUNTS OF MOSQUITO LARVAE.

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For the mounting of mosquito larvae a fluid medium which combines the qualities of fixing, clearing, and preserving offers many advantages over those of a semi-solid consistency. The objection to using a fluid mountant is the difficulty of rendering the preparation permanent. To overcome this difficulty a search was made for a simple and effective method.

The system eventually evolved consists of constructing a small cell on the microscope slide, filling it with the mountant, inserting the larva, and applying a varnish to seal the coverslip. In addition to microscope slides, coverslips, and the mounting fluid, all that is required is a small camel-hair brush and some good quality asphalt varnish. The varnish supplied by the British Drug Houses at 2s. for 100 grammes has proved satisfactory.

The mounting medium used is Amann's lactophenol. Its composition is as follows :—

Carbolic acid	...	...	...	20	ccs.
Lactic acid	...	...	...	20	„
Glycerine	...	...	...	40	„
Water	...	...	...	20	„

This solution makes an excellent mounting medium for the microscopical study of larvae ; in it the specimen retains its natural beauty for an indefinite period, and is sufficiently transparent for the characteristic points of identification to be easily discernible. It is very easy to prepare and, moreover, no filtering is required.

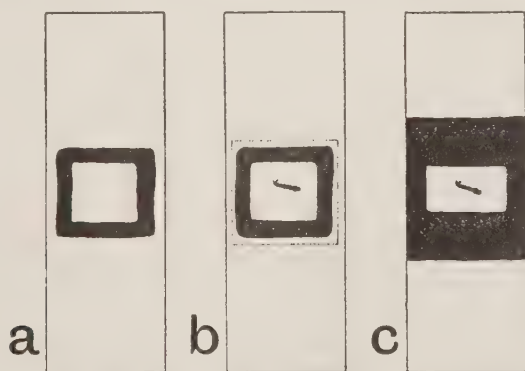


Fig. 1. Stages in the construction of the microscope-slide cell.

The preparation of media usually recommended for the permanent mounting of mosquito larvae is tedious. Gum arabic forms the basis of most of them and involves constant heating over a long period to produce a complete solution, and subsequent filtration, the whole process often taking several days.

The microscope slide is prepared beforehand. Varnish is applied to the tip of the brush and a square is painted as shown in fig. 1, *a*. The cell should be rather less in size than the coverslip to be used. After the varnish has been allowed to dry

another coat is applied if necessary. In this way by deepening the cell with successive layers of the varnish most mosquito larvae can be accommodated. A deep cell to mount larvae such as those of the Megarhine group may be constructed by applying to each subsequent coat of varnish, while still wet, narrow strips of filter paper until the desired depth is attained. For most larvae one thick layer of the varnish suffices.

It has been found convenient to prepare a batch of slides of varying depths at one time and use them as required. There is then no fear of the varnish dissolving into the mountant as it will do if not perfectly dry.

Patton & Evans advocate the use of excavated slides for work of this nature. These are expensive and are not always at hand.

MacGregor employs slides to which a tin ring is affixed. The present method affords a convenient and economical alternative.

A drop or two of the mounting medium is placed in the cell and spread to cover the inside surface. This obviates the danger of air bubbles. By holding the slide horizontal, level with the eye, it is possible to judge roughly whether the mountant is sufficient.

The larva is killed with a few drops of the lactophenol. This is conveniently done in a solid watch-glass by adding the lactophenol drop by drop to a small quantity of water containing the larva. Before the specimen becomes rigid it is lifted out, laid in the mountant, and examined microscopically to see that it is suitably arranged. A clean coverslip is now taken and lowered laterally with the aid of a dissecting needle to rest in the position indicated in fig. 1, *b*, any excess of fluid being withdrawn by means of filter paper and the slide carefully dried. The camel-hair brush, well charged with asphalt varnish, is then diligently applied over the edges of the coverslip to form a seal. Some of the varnish will run beneath, but none will penetrate the cell. The slide is now set aside until the following day, when any moisture about the coverslip should be wiped away before proceeding. To complete the preparation it is advisable to finish off with the application of two coats of the varnish; the first being allowed to dry before applying the second. The slide should now present the appearance depicted in fig. 1, *c*.

Slides constructed in this manner preserve the mosquito larvae in a life-like condition. The hairs are complete in their natural positions, while the comb, pecten, and mentum can be clearly seen. The preparations may be cleaned and handled without fear of damage. Specimens mounted six months ago show no deterioration.

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THE NUTRITION OF MOSQUITO LARVAE, WITH SPECIAL REFERENCE TO THEIR ALGAL FOOD.

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(PLATE XIX.)

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Introduction.

An examination of the algal food of mosquito larvae occurring in some Buckinghamshire ponds was made by the writer in 1928 and the results have been published elsewhere.⁵ The present paper, which arises out of the preceding one, gives an account of work carried out in 1929.

In considering the amount of algae found in the various species of larvae dissected in 1928, it was thought necessary to estimate, if possible, the value that this algal food had as nutrition for the larvae. As has been mentioned in the paper cited above, Pütter⁸ claimed that *Anopheles bifurcatus*, like many other pond species, could live in water devoid of algal food. Many American writers (mentioned in 5) are beginning to share this view. The exact quantitative estimation of the value of algal food to the larvae is a matter for more than one expert. The assistance of the biochemical histologist and bacteriologist will be needed if this question is to be fully answered.

The environment of the mosquito larva, as of all pond-life forms, is so complex, and the factors so diverse, that experimental work ranging over several years will certainly be needed to clarify the intricate relationships existing between animal and vegetable life and their environment.

Many people are working on this problem, obtaining data of algal food, of the physical factors of the environment, and of presence and absence of larvae from ponds where every condition for larval prosperity seems to be satisfied. In my own work the problem was attacked by the following methods:—

1. By an examination of the algae contained in the guts of *Aedes argenteus* and other species after feeding and after starvation of periods of one hour to several days in distilled water at room temperature and at 25° C.
2. By testing the action of a solution of gut cells ground up in distilled water or in glycerol on algae at 30° C.
3. By penetration of stains into algae of gut before and after starvation of larvae.
4. By culture methods.

5. By examination of the more microscopical structure of larvae.

These methods, supplemented by observations in the field, have led to the following conclusions, which will be elucidated in the course of the paper :—

1. Mosquito larvae eat algal food and obtain nourishment from most forms.
2. They are not dependent upon its presence for their existence. Whether the presence of algae has any influence on the determination of what species of larva will occur is not known, but there does seem to be some indirect connection. (See also 5.)
3. Presence of decomposing matter, whether algal or phanerogamic, is beneficial to larvae.
4. Bacteria play an important part in decomposition of all vegetable matter and thus indirectly influence the food relationships of larvae.
5. There is no preference, so far as those larvae examined in the Farnham Royal district are concerned, for any one species of algae. The only preference is one influenced by the size of the mouth—a very catholic one—and by the method of feeding, and this does not seem to be a rigid one in any case.

The following observations suggest that algal food is necessary or at least beneficial :

1. Larvae of *Aedes argenteus* and various native species will eat algae when placed in the same bottle. The higher the temperature the more eagerly does *Aedes* eat algal food.
2. Leaves covered with algae are scraped by *Aedes* (*Ochlerotatus*) *rusticus* and *A. (O.) nemorosus*. The larvae cluster round the algae in the bottle and are found full of epiphytic forms when collected in the field.
3. Certain algae, e.g., *Bacillariales*, lose their contents rapidly in the gut.
4. Though forms like *Anopheles bifurcatus* and *Theobaldia annulata* contain very little algae when found in the field, yet the rapidity with which the gut is filled and refilled may bring enough algae to serve for nutritional purposes.
5. Barber² reared larvae in a pure culture of algae. But Matheson & Hinman⁷ suggest that the larvae found other nutrition in the culture media.
6. Senior-White states⁹ "*Culex bitaeniorhynchus* is attached to *Spirogyra* and cannot live apart from it."

On the other hand it may be remarked that :

1. No tropic reaction towards the presence of algae takes place either in nature⁵ or in the laboratory. To test for such a tropic reaction, a Petrie dish was fitted up with two compartments by means of two large cover-slips fastened with plasticine to the sides of the dish to make a three-sided compartment, leaving a space between the free edges of the cover-slips. Algae were placed in the smaller compartment and larvae in the other and the whole apparatus was placed in the dark. No movement took place. This experiment was varied, two wide tubes fastened together by a rubber cork, through which passed a glass tube of small bore, being used. Water and algae were placed in one large tube, and water and larvae in the other, and the whole apparatus placed horizontally in the dark at 30° C. for *Aedes argenteus* and room temperature for native species. No attempt was made by the larvae to pass from one tube to the other. There is evidently no definite chemical attraction of algae for mosquitos.
2. Forms like *Theobaldia annulata* and *Anopheles bifurcatus* have been found in places where diatoms, etc., are practically absent. Very few were found in the guts.
3. The small forms of the class Chlorococcales and Euglenineae, which were rather common in the pools where *Theobaldia annulata* and *Culex pipiens* were present in 1928, have been found to be very resistant to digestion.

4. The rate of passage of food through the gut may be seen by placing the larvae successively in two very different media and observing the rate at which the new type of food replaces the old. When the larva is actively feeding the whole contents of the gut may be replaced in from 10 to 15 minutes. It has been shown that unless the algal cells are broken they may at the end of this time be plasmolysed in the gut by 20 per cent. Tidman's sea-salt. This indicates that they are still living, in which case it is unlikely that much nourishment has been extracted from them.

5. Water and glycerol extracts of gut cells have very little effect on cells of forms like *Hormidium flaccidum* (Kütz.) A. Br., at 30° C. But this is a matter requiring further study.

6. van Thiel¹⁰ states that food is not the only factor controlling the size of larvae, as he has found that when the available plankton is increased the size of the larvae may be less.

7. Hamlyn Harris⁴ states that the vitality of the larvae is in direct proportion to the concentration of the decomposition products in the water. Here phanerogamic plants will play as important a part as algae.

Changes undergone by Algae in the Guts of Larvae of *Aedes argenteus*.

Larvae of *Aedes argenteus* reared in the laboratory were placed in media containing algae, and the algal contents of the gut were examined. Controls of algae were kept in separate flasks and were examined at the same time in order that corresponding changes in the structure of the cells might be noted if any occurred. As has been mentioned above, when the larva is actively feeding the food passes rapidly through the gut and the digestive action is difficult to observe. It was therefore found better to feed the larvae for a time and then to starve them in distilled water. Under these conditions the food remains in the gut and might be expected to be digested if the larva is capable of using it.

The observed changes in the algae will now be detailed, taking the main groups of algae in order.

Bacillariales.

Diatoms, which were the most numerous forms in most ponds in early spring, lose their contents fairly rapidly. In the first 15 minutes after starvation at 25° C. many of them are changing colour from brown to green. Forms like *Pinnularia tabellaria* (a very common form in East Burnham Common Pond) and *Gomphonema* (common in Golf Lodge Pond), all possessing pores communicating with the exterior, were the ones which lost their contents the first. Very large numbers of these algae were frequently found in the guts. As an example of this see Plate Ia, which shows the diatoms, mainly *Gomphonema*, found in a small portion of the gut of *Aedes (O.) rusticus*.

Zygenemales.

The Zygenemales examined (*Spirogyra* and *Mougeotia*) are forms which lose their contents quickly even at the lower room temperature in the case of *Aedes argenteus*.

Desmidiaceae.

The only Desmid observed was *Cosmarium*, and this lost its contents fairly rapidly. Apropos of this it is again well to note that this form possesses pores.

Oedogoniales.

The cells of *Oedogonium* were again easily emptied. The filament is easily broken up.

Chlorococcales.

None of the species examined in this class lost their contents rapidly or even sufficiently to enable one to say definitely that digestion had taken place.

Microsporales and Heterokontae.

Both *Microspora* and *Tribonema* appear to be digested on starvation of the larvae, but not so readily as *Zygenemales*, etc.

Cyanophyceae.

The only species was *Microcystis aeruginosa*, Kütz., and this underwent a considerable change.

Cladophoraceae.

Cladophora was not eaten by larvae unless it was either cut up or had partly decomposed.

Euglenineae.

Of the Euglenineae observed, *Trachelomonas* alone seemed to be digested. This is a peculiar type, consisting of a naked individual inside a hard case, with a central opening to allow the flagellum to reach the exterior.

Method of Attack of Digestive Fluid of *Aedes argenteus* on Algal Cells.

There does not seem to be any special method of attack on the cells that are digested. The starch sheath of the pyrenoid is not the first part removed, as one would expect if the salivary glands are the organs for producing fluid to digest starch. In some cases, as in *Hormidium flaccidum* (fig. 1e, apical cells of filament), the starch sometimes

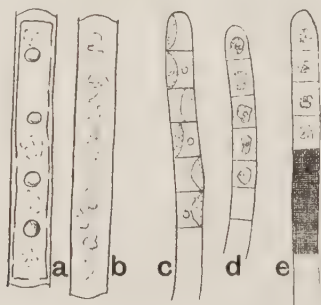


Fig. 1. a, cell of *Mougeotia* in healthy condition, and, b, after digestion; c, healthy cell of *Hormidium*, and d, e, stages of degeneration ($\times 800$).

becomes more diffuse before it disappears, but this is after the general protoplasmic structure of the cell has been broken down. The protoplasm is probably the part which contributes to the nourishment of the larva.

In *Spirogyra* the forms used were *S. tenuissima* (Hass.) Kütz. and *S. varians* (Hass.) Kütz., both forms in the early fruiting stage and so having cells filled with oil. The chloroplast loses its definite form, gradually becomes full of granules (fig. 2c) which are at first green, then brown and finally disappear; or the cell becomes full of a "wash" of protoplasm coloured green (fig. 2, b & c). This green "wash" appearance was seen in many algae after the larvae had been starved a few days. *Hormidium flaccidum* (fig. 1) underwent a similar change preceded by a plasmolysis of the protoplast. Such plasmolysis was in most forms the first sign of digestion. Similar results were obtained with *Tribonema* and *Microspora*, but these did not change so rapidly.

Scenedesmus quadricauda (Turp.) Bréb., a Chlorococcale, underwent comparatively little change during several days starvation of the larva (Plate XIX, figs. 2 & 3) at 25° C., the pyrenoid generally remaining. *Scenedesmus* cells are not easily plasmolysed even in the healthy state with 20 per cent. Tidman's sea-salt, so that it cannot be stated whether the cells were living or not at the end of this time.

Even the same species of alga does not always behave in the same way. The *Scenedesmus* used was one from a culture, and the alga was in the *Dactylococcus* stage. Some *Scenedesmus* obtained from a pond underwent slightly greater change. This difference may be due to the fact that a necessary species of bacterium was not present in the former case. It is quite possible that *Scenedesmus* in a certain environment will undergo still more digestion. If we assume that the pH of the gut cavity is approximately that of the water environment, it is quite possible that the adult will lay eggs where the pH is such that it is within the range of alkalinity or acidity necessary to digest the *Scenedesmus*.

Some fourth instar larvae of *Aedes argenteus* placed in some water smelling evilly of blue-green algae, chiefly *Microcystis aeruginosa*, Kütz., fed on the material and

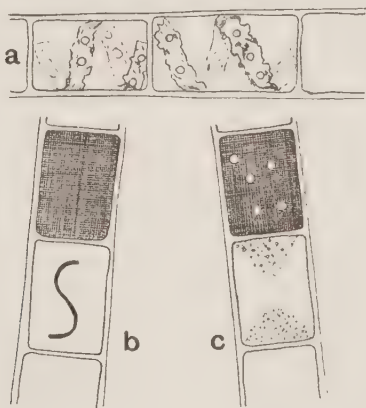


Fig. 2. Cells of *Spirogyra*: a, healthy cells; b, c, stages of degeneration ($\times 300$).

pupated, but first instar larvae died. In the former the blue-green cells turned green and lost all their gas-vacuoles and practically all their surrounding jelly. Larvae placed in a basin containing *Cladophora* would not eat it until the following day, when putrefaction had set in. But if the *Cladophora* was first cut up, it was readily eaten in the fresh state.

In all the above observations it must be borne in mind that the changes generally occurred after several hours to many days starvation. In some cases, as in *Spirogyra*, loss of cell contents was seen after a few hours. It must be remembered that under normal conditions no such starvation takes place, and the gut is being repeatedly replenished. The algae do not yield up their total food value to the larvae.

In most cases the walls of the algae apparently remained unchanged. The cellulose wall still gave a pink reaction to calcium-chloride iodine solution and was still dissolved by Schweitzer's reagent. But the walls of most algae are complex in structure, and their investigation by biochemists is by no means complete.¹¹

Only in *Spirogyra* and *Cladophora* were the walls noticeably swollen after being in the gut. The walls of Diatoms, *Tribonema* and *Spirogyra*, are impregnated with pectic substances, salts of pectic acid, arabinose and galactose. It is interesting

to note with regard to the problem of digestion that the larva may have a gut full of apparently undigested starch with numerous bacteria and yet the gut cells be crowded with numerous fat-like globules, a sign of a nutritious meal. In this connection it may be recorded that some larvae were placed in milk, which they absorbed rapidly until the gut cells were crowded with globules.

After the first few hours of starvation the algae do not undergo much further change, so that what has been taken out in this time is all that is used. It will be seen, then, that in the larval method of feeding 75 per cent. at least of the algae eaten may leave the gut practically untouched.

Digestion of Algae in vitro.

Fifty guts of *Aedes argenteus* were washed in distilled water and were ground up with washed Kieselguhr in 2 cc. of distilled water with a drop of 5 per cent. thymol and placed in a 30° C. water-bath together with algae, mostly *Hormidium* and *Mougeotia*. The same was done with a glycerol extract. The pH values taken were 6.0 and 7.0, very dilute HCl being used to produce the acidity. Very little result was obtained. After 30 minutes the cell was plasmolysed and looked unhappy, but the pyrenoid still showed clearly. The diatoms were brown. There was no further effect after several hours. The experiment was again tried, using no thymol, but with the same meagre result. Several other factors besides pH enter into a problem of this kind, which might be made a subject for thorough investigation.

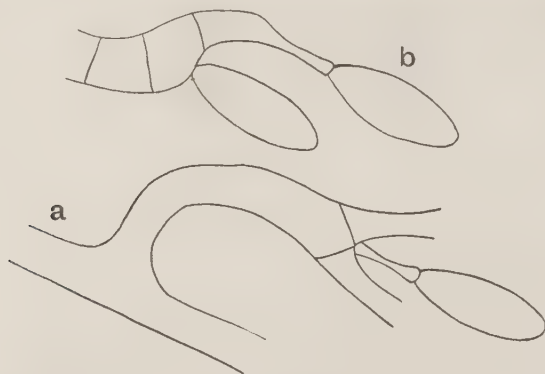


Fig. 3. Fungi: *a*, found in *Aedes argenteus*; *b*, in *Aedes nemorosus* ($\times 1,230$).

Interesting occurrences of fungi in the internal anal regions of the guts of *Aedes argenteus* and of *A. (O.) nemorosus*, found in Burnham Beeches, are to be noted (fig. 3). These fungi are very noticeable when the larvae are starved. Whether their relation to the larvae is symbiotic, having some connection with digestion, or whether they are parasitic, remains to be determined.

Penetration of Stains into Algal Cells before and after Digestion, and into Gut Cells of Larvae.

A number of stains, including Biebrich scarlet, methylene blue, methyl blue, and basic fuchsin, were applied to the algae in the gut and in the control flasks. No definite results were obtained from this beyond the fact that the algae which stained on the whole better in the healthy condition were of the same species as those that were better digested in the gut. Forms like *Scenedesmus* took up stains very slightly. Vital stains like neutral red and methylene blue were absorbed with great rapidity

by the gut cells. The stains were taken up so well that they resulted in red and blue larvae swimming about in a liquid of the same colour. The gut cells take up a more or less uniform red, but assume many shades of blue. The way of absorption lies through the gut cells, the exterior cells becoming red or blue last. The action of the amino-compound methylene blue, $(\text{NO})\text{C}_4\text{H}_4\text{N}(\text{CH}_3)_2\text{NH}_4\text{S}$, in the gut cells is very interesting, different colours being assumed by the cells. The following is an account of the stages in the absorption of methylene blue by the gut cells of *Aedes argenteus* at 30°C . :

After 15 minutes, the cells just below the caeca are blue, the central space inside the peritrophic membrane is slightly blue, and some of the cells of the caeca are slightly blue. After 40 minutes, blue granules (small globules) appear in some of the cells of the caeca, green fluid in the lumen of the caeca, and blue granules in some of the cells below the caeca. After 70 minutes, all the caecal lumen is green and there are also quantities of greenish fluid inside the peritrophic membrane; the cells below the caeca and cells above the Malpighian tubules are distinctly blue. After 105 minutes, the blue granules in the cells above the tubules are larger than those in the caecal region. The same difference in size of granules was noticed when milk was being absorbed. The tubules are now faintly blue, and some of the cells of the lower part of the gut have two sets of granules—large blue ones and small purple ones. After a few hours a few cells just below the caeca are rose-pink. All the cells of the gut are now becoming blue, but the central region is still only slightly blue. After $5\frac{1}{2}$ hours many cells in the caeca and some cells above the tubules possess fairly large globules containing blue granules. The next morning many of the cells, especially those above the tubules, have become dirty brown in colour.

Larvae placed in neutral red over-night had their granules stained very well. Some cells were purple, some yellow, and the caecal lumen was full of a very red liquid.

This account of the absorption of stains does suggest that the pond-water and the contents of algae in solution are taken up in the same way.

Culture Work on Algae.

A number of experiments on the rearing of larvae in various culture solutions were made with the object of determining whether the presence or absence of algae had an effect on the rate and manner of growth of the larvae. Some of the larvae were obtained in the first instar stage from a pond, and the *Aedes argenteus* were reared from the egg. As a rule no effort was made to sterilise the eggs, because they were afterwards to be put into non-sterile solutions.

Two groups of experiments were performed on the first instar larvae of *Aedes (Ochlerotatus) rusticus*, and the results have been combined. Some 25 or 30 larvae were put into 250–350 cc. of various media in 500 cc. Bohemian flasks. The pH was kept constant (6.0–7.0) and the temperature kept at 15°C . by means of a water-bath. The media were often changed, and care was taken that the pH of the fresh media did not differ considerably from the old. The solutions used were (1) sterilised distilled water; (2) sterilised distilled water and living algal plankton; (3) sterilised distilled water and dead plankton; (4) filtered pond-water (filtered through a filter-paper); (5) pond-water.

Of the 55 larvae put in sterilised distilled water none lived beyond the first instar stage. In sterilised distilled water plus living algal plankton, 13 matured to the fourth instar stage and 7 pupated. In distilled water with dead plankton, 4 developed to the fourth instar stage and 3 pupated. In filtered pond-water, 37 developed to the fourth stage, but then died. In pond-water with very little algae, and that unicellular, 9 developed to the fourth stage and 2 pupated. The maximum widths of the heads measured between the bases of the antennae of the above larvae were

respectively 237–254 μ , 227–240 μ , 224 μ , and 256–282 μ . The sizes of the head at the fourth instar stage were nearly always less than in nature. The average width of those found in the pond was 263 μ . The time taken by these larvae to reach the fourth stage was practically the same in each case, being 21 days. Here the presence of algae does not seem to alter the rate of development of the larvae. The size of the larvae did not differ appreciably, but those grown in filtered pond-water were thinner in appearance.

Larvae grown in tap-water or in water containing dissolved salts have guts containing crystals. Of 20 larvae placed in water filtered through a Chamberland filter F, 9 developed to the third instar and 2 to the fourth.

Similar experiments were performed on *Aedes argenteus* at 25° C. In this case the solutions used were (1) hay infusion; (2) pond-water; (3) filtered pond-water (filtered through filter-paper); (4) distilled water plus algal plankton. Adults were reared in the filtered pond-water, so that the food found in this water was apparently sufficient. Plate XIX, fig. 4 shows the appearance of a longitudinal section of the gut of *Aedes argenteus* reared to the fourth instar stage in filtered pond-water. It will be seen that the contents are granular and amorphous, there being no sign of algae. The times taken by larvae to develop from the egg to the pupa were as follows:—

In hay infusion, 6 days; in pond-water, 6 days; in filtered pond-water, 18 days; in distilled water and algal plankton, 6 days.

This difference in time for the larvae of *Aedes* to develop in filtered pond-water from that taken in other media, when no difference was noted in the cultures of *Ochlerotatus*, is remarkable. It is quite probable that the quality of filtered pond-water differs from time to time. The pond-water used for *Aedes argenteus* was rich in algae, the following species occurring: *Peridium* sp., *Ankistrodesmus falcatus* var. *acicularis* (Corda) Ralfs, *Scenedesmus quadricauda* (Turp.) Bréb., *Micractinium pusillum*, Fresen., *Micractinium radiatum*, Chod., *Lagerheimii genevensis*, Chod., *Trachelomonas volvocina*, Ehrenb., *Trachelomonas hispida* (Perty) Stein, *Dictyosphaerium ehrenbergianum*, Naeg., and *Pediastrum boryanum* (Turp.) Menegh. That used for *Aedes* (O.) *rusticus* contained practically no algae. It is possible that in the pond-water used for *Aedes argenteus* the algae had used up the various salts in solution, so that not enough were left for the larvae. The sizes of the heads of the larvae grown in the different solutions differ considerably, those of the larvae grown in hay infusion and pond-water being much larger than those grown in filtered pond-water and in distilled water plus algae. Again, the larvae grown in filtered pond-water were less sturdy in build.

Cytological Investigation.

Examination of histological preparations of the gut and gut cells revealed no character (although it was done with the idea of finding one) that would definitely suggest that algal food was advantageous. The guts were fixed in Carnoy's or Flemming's without acetic acid and stained with Delafield's haematoxylin. Small granular bodies which sometimes appeared in the cells could not be correlated with any diet. Goblet cells were present in sections of guts made from larvae reared in most solutions, and the whole structure of the gut is very like that observed by van Gehuchten in *Ptychoptera contaminata*.³

If the digestive fluid is contained in the goblet cells it must be a fluid of small osmotic pressure. The goblet cells will completely plasmolyse with 20 per cent. Tidman's sea-salt. Perhaps this explains why only algal cells either possessing pores or having low osmotic pressures seem to be digested easily.

Conclusion.

From these methods of approach it will be seen that the whole question of the importance of algal food to the larva is very involved. The part played by algae may be one of balance, turning an otherwise nearly suitable environment into an eminently suitable one; or it may be important only indirectly, supplying decomposition products which dissolve in the pond-water and are absorbed by the larvae with other organic matter.

Summary.

1. Algae are ingested by many species of mosquito larvae and appear to form an important part of the food of these larvae.
2. The algae are digested in the gut, but the digestion is often by no means complete.
3. It is quite possible that the rôle played by the algae may also be assumed by other forms of organic matter, for larvae may be reared to maturity in solutions containing little or no algae.
4. Different algae react differently in the guts of the larvae, some being noticeably digested and some hardly at all.
5. Those algae which are digested the most are easily stained and are forms of low osmotic pressure.
6. Cytological investigation revealed no character that indicates that algae are an especially nutritious diet.

This work was carried out at the Farnham House Laboratory of the Imperial Institute of Entomology, Buckinghamshire, under the guidance of Dr. P. A. Buxton, to whom my thanks are due.

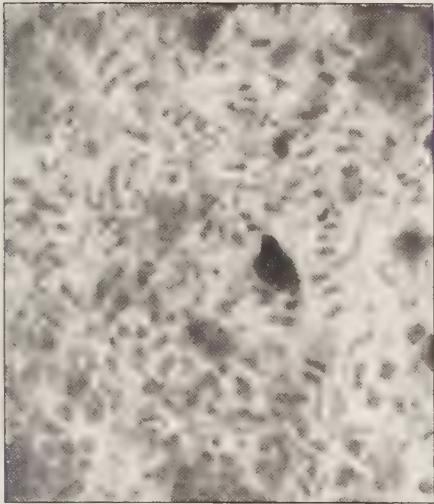
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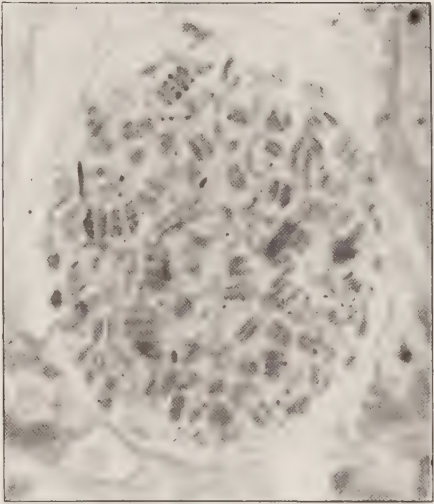
EXPLANATION OF PLATE XIX.

- Fig. 1. A sample of the contents of the gut of *Aedes (Ochlerotatus) rusticus* found in Golf Lodge Pond. Notice the very large numbers of diatoms (*Gomphonema angustatum*) mixed with débris of the pond. Filaments of microspora may be seen in both the lower corners.
- „ 2. Transverse section of the gut of *Aedes argenteus* showing the condition of *Scenedesmus quadricauda* after 30 hours starvation of the larva at 25° C. Notice that the algal cells have not lost their contents. Some of the pyrenoids can be faintly seen.
- „ 3. A portion of the gut of *Aedes argenteus* showing the condition of cells of *Scenedesmus quadricauda* (*Dactylococcus* stage). The larva has been starved for six days at 25° C. Very few of the cells have lost their contents. The slight plasmolysis of the cells is due to their being mounted in glycerine jelly.
- „ 4. Longitudinal section of the gut of *Aedes argenteus* which has been reared to the fourth instar stage in filtered pond-water. The contents are granular and amorphous, brown in colour. No algae are to be seen.

Magnification somewhat less than 400.



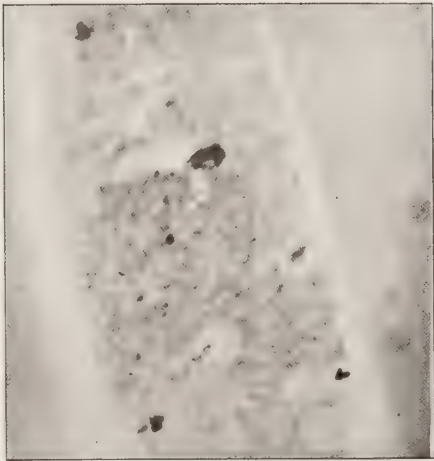
1.



2.



3.



4.

Gut Contents of Mosquito Larvæ.

THE QUEENSLAND SPECIES OF *CALLIPHORA* SUBGENUS *NEOPOLLENIA*.

By G. H. HARDY,

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An effort to ascertain the specific status of described Australian Calliphorine flies was started in 1922, when some conceptions of synonymy gathered from various sources were published by Johnston & Hardy. In 1925, Patton gave his opinions concerning the identity of the species after examining many types in Europe. In 1926, I drew attention to discrepancies that were at that time apparent in Patton's views, and gave further information that had accrued during the three previous years. In 1927, Bezzi revised the genus over a wide area, and his paper covering the Indo-Australian species is the outstanding contribution in so far as many genera previously proposed are reviewed. There followed in the same year a paper by Malloch on specific characters, which paper is highly suggestive and constructive, but unfortunately some of the species of earlier authors are incorrectly determined; and, indeed, this defect is noticeable throughout the series of papers referred to above, many names being perhaps wrongly placed as synonyms or species needlessly redescribed as new.

Bezzi and Malloch have used the bristles of the scutellum and thorax for discriminating the species with more or less success. With certain alterations their characters may be used advantageously, but it must be recognised that the thoracic bristles are subject to variation, slight in some cases but quite noticeable in others.

The *presutural acrostichals* are very useful, as they are fairly constant. Not infrequently an extra pair may be developed anteriorly to the normal ones; in such a case the latter can be recognised by their position. If three permanent pairs occur, the posterior ones are quite adjacent to the transverse suture, whereas if only two pairs occur, the posterior ones are remote from the transverse suture.

There are several *scutellar bristles*, one pair being placed dorsally, the others along the margin. The pair at the apex of the scutellum is referred to as the apical marginals, and the others are called lateral marginals. All of them are long and strong, and must not be confused with weaker ones that sometimes appear, nor with those occasional submarginals liable to be found very near the base of the scutellum. In *Neopollenia* there are normally three pairs of marginal bristles, but in two species there are four.

The space between the ocellar triangle and the frontal lunule, bounded laterally by the eyes, is termed the "frons." Measurements are taken along the median line between the anterior ocellus and the lunule. The width of the frons is measured half-way along the median line. The proportion of length to breadth is measured only in the female, the width in the male at its narrowest point being expressed in other ways. There is often a sheen on the frons, not to be confused with the general colour over which it lies, and it is best seen when viewed from above. The sheen is usually silvery in species of *Neopollenia*, but is golden in some of them.

At first the genitalia were studied from mounts made on micro-slides, some of which were prepared as far back as 1922. It became evident, however, that mistakes in identification were liable to be made, and the general methods adopted for the preparing of genitalia did not lend themselves to accuracy of delineation or description. The species are now being re-examined, using fresh material, under the method described below.

Old specimens do not make satisfactory mounts, but they may be prepared by extracting the genitalia, boiling in distilled water, and then passing through the same

simple process. The risk of damaging membrane and otherwise spoiling the mount to be prepared is about as much as that run when treating genitalia in caustic potash, but the tendency for the parts to become distorted is not so great. When genitalia are extracted from recently killed material there is little risk of breakage or distortion if the following process is adopted :

The parts are placed in turps-phenol till cleared. The aedeagus, claspers, forceps and accessory plates, can then be dissected without damage, and all are mounted together in canada balsam or other suitable medium on a celluloid mount with a celluloid coverslip ; the mount is then transfixed by the pin passed through the thorax of the fly.

My usual custom is to extract genitalia one day and mount them the next, but they can be left in the clearing fluid for a week or more without harm, by which time the parts can be disjointed with little manipulation, but are brittle. On the other hand, they can be mounted within a few minutes of being placed in the clearing fluid, and thus the operation of mounting can be performed at any time that may be convenient.

The scheme for placing the Australian Calliphorines into subgenera is based on Bezzi's arrangement :—

Adichosia, Surcouf ; type *Ochromyia hyalipennis*, Macquart.

Proekon, Surcouf ; type *Ochromyia lateralis*, Macquart.

Neopollenia, Brauer ; type *Musca stygia*, Fabricius.

Onesia, Desvoidy ; this name is used for a complex not covered by the three previous subgenera.

Calliphora, Desvoidy ; type *C. erythrocephala*, Meigen. This species has been introduced into Australia and would seem to be subgenerically distinct from the indigenous forms. Malloch pointed out that *Onesia* has priority over *Calliphora*, and Townsend is of opinion that the name is erroneously used in the sense here understood. Bezzi states that the separation of the two subgenera is not an easy matter.

The first three subgenera seem to be confined to the Australasian region. Two species of *Neopollenia* cover the coastal range from Queensland to Tasmania, but neither has been found north of Brisbane ; both, however, cover the south coast as far as Adelaide. These species, *C. stygia* and *C. tibialis*, go under names of long standing, but there is no assurance that the species now known under these names are those originally described as such.

C. australis occurs in Western Australia, where another species of the *rufipes* group is also found. *C. rufipes* and *C. hilli* are both from Victoria, which State again seems to have a complex of species in addition to *stygia* and *tibialis*. Malloch has confused *C. hilli* with still other species occurring in Queensland and New South Wales, but owing to the inadequacies of his description and figure one cannot fix his species, but it seems very certain that he had two forms under this name. Both these forms are described below under new names. *C. auriventris* and another new species, described here as *C. canimicans*, are remarkably distinct from all the others. In all, there would appear to be some fourteen species known, nine of which are in my own collection ; some of these and five others are in Dr. Mackerras' collection at Canberra. Dr. Mackerras has kindly given me specimens of one of his species, and particulars of others, thus making it possible to prepare a key to the Queensland species. The subgenus *Proekon* is also widely distributed and composed of several species. Again there is considerable confusion caused by the manner in which the names have been applied, and it seems certain that one, at least, of the names recently proposed by Malloch is not needed.

Adichosia, *Onesia* and *Calliphora* are subgenera of no particular economic interest in Australia, although one species in the first of these is a notorious blower of blankets. *Adichosia* contains but two known species, rather similar in coloration but very distinctive in structure. One occurs from Sydney to the northern parts of Queensland, the other is limited to Tasmania. *Onesia* is generally distributed, with numerous species.

Subgenus **Neopollenia**, Brauer.

This subgenus is to be recognised by the abdomen being completely or mostly covered with a deep golden sheen which varies with the incidence of the light. It comprises ten species, all of which are known to me, with one exception.

The four species occurring in Brisbane can mostly be distinguished by their habits. *C. stygia* is a relatively boisterous and venturesome winter and spring species that readily invades houses. *C. canimicans* is similarly boisterous, but does not enter houses, and the entirely black legs make it readily recognisable in the field.

C. ruficoxa and *C. fallax* appear to have identical habits, and apparently both occur in Brisbane throughout the year, but they do not necessarily reach their maximum in numbers at the same time. Both, like the next species, are rather retiring in habits and rarely enter dwellings.

C. tibialis, as originally pointed out by Professor T. Harvey Johnston, frequents hedges and has now been found fairly plentifully during September, haunting a hedge of *Duranta* in the University grounds. It also occurs in the bush around Brisbane where the underscrub is fairly thick. It occurs during most months of the year, but is often very scarce. Large specimens are liable to be confused with *C. canimicans*, but I have never found these inhabiting the same type of locality, and in any case the boisterous flight of the latter is ample enough to distinguish them.

Key to Species of Subgenus *Neopollenia*.

1. Male with facets of eyes in two contrasting sizes, the upper ones being the larger, eyes almost contiguous; in female, eyes extremely far apart, the frons length in proportion to width being 20 : 32; three pairs of presutural acrostichals and three marginal scutellars; femora, tibiae and practically all pleural hairs of thorax, and hairs on underside of abdomen yellow *stygia*, F.
Male with facets of eyes much less contrasting in size, those above being but little larger than those below; eyes usually separated in male and never so wide apart in female 2.
2. Three pairs of marginal bristles on scutellum 3.
Four pairs of marginal bristles on scutellum; two presutural acrostichals; at least some of the pleural hairs yellow; femora and tibiae entirely black; frons of female as long as wide 7.
3. Abdomen and thorax with yellow hairs; tibiae entirely yellow and femora usually yellow, but may be black at base 4.
Abdomen and thorax never with yellow hairs; two presutural acrostichals; eyes of male almost contiguous; frons of female as long as broad; sheen apparently never present on frons; tibiae brown; femora may be brown, but usually black *tibialis*, Mcq.
4. Three pairs of presutural acrostichals, the last of these being adjacent to the transverse suture 5.
Two pairs of presutural acrostichals, the last of these being remote from the transverse suture 6.
5. Anterior coxae unicolorous with the femora, being without trace of any other coloration; eyes of male separated by the width of two ocelli; frons of female as long as broad; frontal orbits with a golden sheen; Queensland
fulvicoxa, sp. n.

Anterior coxae covered with an ashy grey or yellow substance and hence differently coloured from the femora; eyes of male separated by the width of the ocellar triangle; frons of female longer than broad (30:20); frontal orbits with a silvery sheen; Western Australia ? *australis*, Bdv.

6. Eyes of male separated by the width of the ocellar triangle; frons of female broader than long (26:20); frontal orbits with a strong silvery sheen

? *rufipes*, Mcq., ? *hilli*, Patton, &c.

Eyes of male separated by the width of two ocelli; frons of female as long as broad; frontal orbits with a golden sheen; Queensland ... *fallax*, sp. n.

7. Abdomen with yellow hairs; eyes of male separated by about the width of the ocellar triangle; frontal orbits with a silvery sheen ... *canimicans*, sp. n.

Abdomen without yellow hairs; eyes of male separated by little more than the width of one ocellus; frontal orbits with a golden sheen; wings more strongly suffused with yellow than usual *auriventris*, Mall.

A West Australian species that has many characters in common with *C. stygia*, received from Dr. I. M. Mackerras, may be *C. australis*, Bdv., but there is at least one other species from that State, a form that comes into the *rufipes* complex to which *C. hilli* also apparently belongs.

I use the name *rufipes* in a wide sense to cover what may possibly be a closely connected group, for the known males have their genitalia comparable to those of the species here named *C. fallax*. This complex ranges from Perth to Adelaide, Melbourne and Hobart. *C. fallax* I believe reaches to Sydney, but I have not yet studied the genitalia of specimens from that city and base this idea on two males which seem to conform in every respect with Brisbane specimens. Dr. Mackerras has yet another species that seems to run to the fifth couplet in the key, but is quite distinctive in its genitalia and is represented by a unique male. In all, some fourteen species have been distinguished on the genitalia, but only five of them are yet available in numbers sufficiently numerous for description.

Calliphora stygia, F.

Musca stygia, Fabricius, Spec. Ins. ii, 1781, p. 438; Wiedemann, Auss. zweifl. Ins. ii, 1830, p. 393.

Calliphora villosa, Desvoidy, Essai Myod. 1830, p. 437.

Musca laemica, Walker, List Dipt. B.M. iv, 1849, p. 906.

Calliphora stygia, Schiner, Novara Reise, Dipt. 1868, p. 309.

Musca stygia was redescribed from the Banks collection as from "Terra nova Americae," supposedly Newfoundland, but Schiner records this as an error. The description would apply to several species, but as Patton has seen the type, the name may be regarded as belonging to the form identified by him as such. It is possible, however, that Patton did not distinguish between the females of *C. stygia* (as here understood) and those of the *rufipes* complex.*

Calliphora villosa, Desv., was placed as a synonym by Schiner.

Musca laemica, Walker, on account of the wide distribution given with the original description, must be regarded as a complex.†

The species can be readily recognised by the eyes of the male, and by the widely set eyes of the female, the inner margins of which are strongly bowed. The frons of

* [Miss Aubertin has kindly examined the type and informs us that it is a female with a broad front and agrees entirely with the definition of *stygia* adopted by the author.—Ed.]

† [This species was first described by Adam White (Dieffenbach's Travels in New Zealand, ii, 1843, p. 291) from New Zealand only.—Ed.]

the female varies slightly, measurements of proportions give 20 : 31.2 and 20 : 33.4, but these are extremes, the average being nearer that given in the key ; measurements are based on Brisbane specimens only.

QUEENSLAND : Brisbane, May to September, but very scarce in May and June, and infrequent in July. NEW SOUTH WALES : Sydney, abundant during September, but apparently not occurring in summer. SOUTH AUSTRALIA : Adelaide, August to May. TASMANIA : Hobart, Mt. Wellington and Zeehan, January and February ; but generally distributed throughout the island and abundant in summer, and not seen in winter.

***Calliphora fulvicoxa*, sp. n. (fig. 7).**

Calliphora ? *hilli*, Malloch (part, *nec* Patton 1925), Proc. Linn. Soc. N.S.W., lii, 1927, p. 309.

It seems evident that Malloch misidentified *C. hilli*, Patton, and probably this is one of the forms he confused under that name, though I have seen no hypopygium that conforms to his drawing. In the aedeagus the curvature of the dark strut

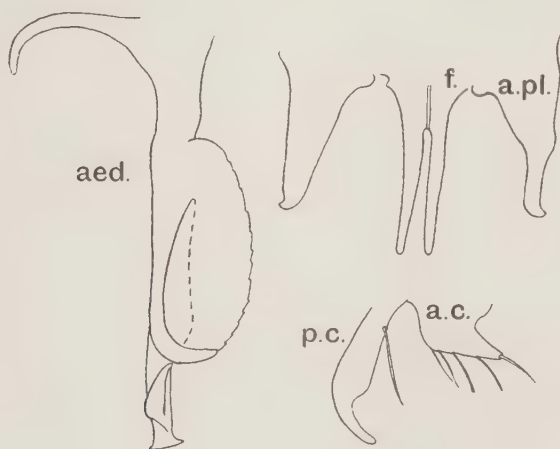


Fig. 1. Male genitalia of *Calliphora fulvicoxa*, sp. n. : *aed.*, aedeagus ; *f.*, forceps ; *a.pl.*, accessory plate ; *p.c.*, posterior clasper ; *a.c.*, anterior clasper.

differs, though the shortness of the apical part beyond it conforms to the present species, but the forceps and accessory plates disagree with this and are more like those of the following species.

New Zealand specimens were identified by Malloch as being *C. hilli* ; this is very uncertain, and it is probable that they are not really the same as the Australian species.

Description.—In the male the frons is one-seventh the width of an eye, about the width of two ocelli. In the female the frons is as long as broad. The sheen on the frons, when present, is invariably golden. Three presutural acrostichals are present, the third pair being adjacent to the transverse suture. There are many yellow hairs on the pleurae, as also on the venter. The anterior coxae are coloured like the femora, having no dark stains or ashy covering. The genitalia have the accessory plates with a small pointed projection at the apex ; this minute protuberance is visible when viewed from most angles and offers a contrast to the rounded shape of

all the other species examined. The aedeagus contains dark strut-like lateral supports that are rather slender, but sharply curved towards their apex, the apical portion beyond this being shorter than is usually found in the subgenus. In these two characters it is to be distinguished from all the other species yet known. The broad aedeagus and the shape of Lowne's spine are also distinctive, and the shape of the posterior clasper differs from that of the next species also.

QUEENSLAND : Brisbane, throughout the year.

Described from 25 males and 25 females.

***Calliphora fallax*, sp. n. (fig. 2).**

Calliphora ? *hilli*, Malloch (part, nec Patton 1925), Proc. Linn. Soc. N.S.W., lii, 1927, p. 309.

Malloch seems to have this species under the name *C. hilli* as well as the previous one. It is to be distinguished from *C. fulvicoxa* by the differently coloured coxae as well as by the absence of the third pair of presutural acrostichals; hence the posterior ones in this species are situated remote from the transverse suture.

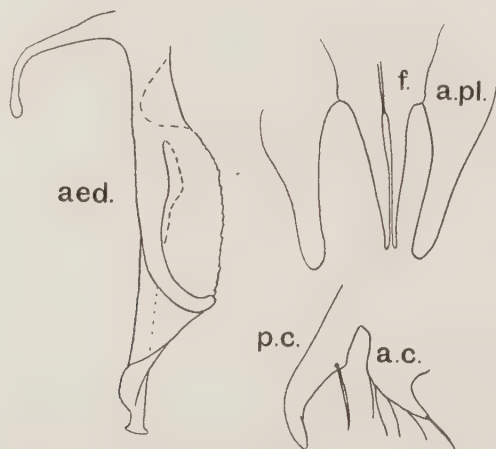


Fig. 2. Male genitalia of *Calliphora fallax*, sp. n. : lettering as in fig. 1.

Description.—In the male the frons is one-seventh the width of an eye, about the width of two ocelli; in the female, as long as broad. The sheen on the frons, when present, is invariably golden. Only two presutural acrostichals are present, the second being remote from the transverse suture. There are many yellow hairs on the pleurae, as also on the venter. The anterior coxae are dark in colour, deeply stained and with an ashy grey covering, being therefore markedly contrasted with the femora. The genitalia have the accessory plate rounded at the apex, as normally found in the subgenus. The aedeagus has the dark strut-like lateral supports gently curved towards their apex, the apical portion beyond this being elongate.

QUEENSLAND : Brisbane, April to September, but probably occurs throughout the year.

Described from 30 males and 50 females.

Calliphora canimicans, sp. n. (fig. 3).

Calliphora ? *tessellata* (Macquart) Bezzi, Bull. Ent. Res., London, xvii, 1927, p. 245.

Bezzi described a species from Victoria under the name *C. tessellata*, Macq., but Malloch is of the opinion that Macquart's species is *C. tibialis*, and Patton, who has seen the type, considers it to be a specimen of *C. dispar* (of the subgenus *Onesia*). *C. tessellata* is from New Guinea and even if it belongs to the subgenus *Neopollenia*, it is unlikely to be conspecific with this or *C. auriventris*, Mall.

This species may be readily mistaken for *C. auriventris*, which it closely resembles, but it is distinguished by the yellow hairs on the abdomen and by other characters, and the black legs distinguish it from *C. stygia* and its allies.

Description.—Eyes of the male separated by the width of the ocellar triangle. The frons of the female is about as long as broad. The frons has a silvery sheen,

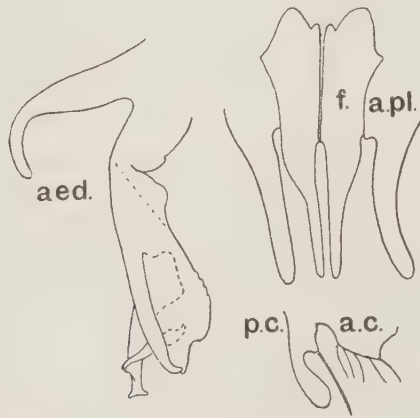


Fig. 3. Male genitalia of *Calliphora canimicans*, sp. n.: lettering as in fig. 1.

the ground-colour being yellow. There are many yellow hairs present on both the thorax and abdomen, the legs, however, are entirely black and the scutellum has four instead of the usual three pairs of scutellar marginal bristles.

QUEENSLAND :] Brisbane, June to September.

Described from 60 males and 18 females.

So far this species has only been taken in the University grounds and in a very small adjacent area within the Botanical Gardens; the whole area combined does not exceed one acre, and yet specimens have now been found there in large numbers over two winter seasons. So far as yet known, they become plentiful in May, persist throughout the winter, and become very numerous in September, towards the end of which month they disappear. The males are much the more abundant, the females being comparatively scarce and usually settling on the ground. Like other species in Brisbane, it is most easily found after cold nights, frequenting warm spots, sheltered from the breeze, sporting in the sunshine from about 9 a.m. to 10 a.m.; I have searched for them at other hours of the day without avail, but as the spring comes on they seem to persist on the wing for longer periods.

***Calliphora tibialis*, Macq.**

Calliphora tibialis, Macquart, Dipt. Exot., suppl. i, 1846, p. 195.

Somomyia tibialis, Brauer, Denkschr. Akad. Wiss. Wien, m.n. Cl., cviii, 1899, p. 542.

Paracalliphora tibialis, Townsend, Canad. Ent., xlviii, 1916, p. 151.

Calliphora tibialis, Patton, Philippine Journ. Sci., xxvii, 1925, p. 40; Hardy, Proc. Roy. Soc. Queensland, xxxviii, 1926, p. 172; Bezzi, Bull. Ent. Res., xvii, 1927, p. 245; Malloch, Proc. Linn. Soc. N.S. Wales, lii, 1927, p. 308.

Under this name most authors seem to refer to a well known and common species, which, however, differs in one particular from the original description, for the words "Front noir, un duvet blanchâtre sur les côtés" cannot properly be applied to it. Moreover, Brauer placed the type as a specimen of *stygia*, with which he may have confused the *rufipes* complex which does bear the character cited. Patton, who also seems to have seen the type, states that the legs are darker, but gives hardly any more information about it. I have little doubt that Patton refers to the present species in his own descriptions, and the same remark may be applied to Townsend, Bezzi and Malloch; I have therefore provisionally accepted the name.

The limits of the species are also somewhat vague, as most authors write as if they had seen no colour variations. I have several variations before me that show the legs may become entirely brown or almost so. A form that might prove a distinct species is in Mr. F. E. Wilson's collection; this is a unique male having the eyes about twice as far apart as normal; it is from Victoria.

Description.—Eyes of the male almost contiguous, not further apart than the width of one ocellus. In the female the frons is as long as broad. The sheen of the frons is never present, nor are there any yellow hairs on the thorax and abdomen. Two presutural acrostichals are present, the posterior ones being remote from the transverse suture, and there are only the three usual pairs of marginal scutellars. The legs are somewhat variable in coloration; both the femora and tibiae may be brown, but usually the femora are black and sometimes the intensity of the brown on the tibiae is so deep that they appear to be black. The hypopygium is longer than normal in the subgenus, and the various parts are not unlike those of *C. fallax*. The aedeagus has its strut more curved, and the part beyond it is much longer, whilst the accessory plates broaden out towards their apex, being broadly rounded there.

Widely distributed from Southern Queensland to Tasmania and South Australia. In Brisbane it has been taken from July to February, but is abundant only in September.

NEW THYSANOPTERA FROM SOUTH AUSTRALIA.

By GUY D. MORISON, Ph.D., M.Sc.(Lond.),
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I am indebted to the Imperial Institute of Entomology and to Mr. F. Laing, of the British Museum, for submitting to me for classification a small collection of Thysanoptera from Dr. J. Davidson, of the Waite Agricultural Research Institute, Glen Osmond, South Australia. The specimens reached me well preserved in alcohol, in tubes each labelled "S. Australia, Adelaide, month-1929, Dr. J. Davidson, from lucerne, rose-bushes, etc." All measurements in this paper are in μ .

Suborder TEREBRANTIA.

Family OROTHRIPIDAE.

Genus **Desmothrips**, Hood.

Owing to the apparent variability of some of the characters of this genus, I describe it thus: Female, male, 5-9 antennal segments closely united, single sense areas on segments 3 and 4; maxillary palpi with 7-8 segments; labial palpi with 3-4 segments.

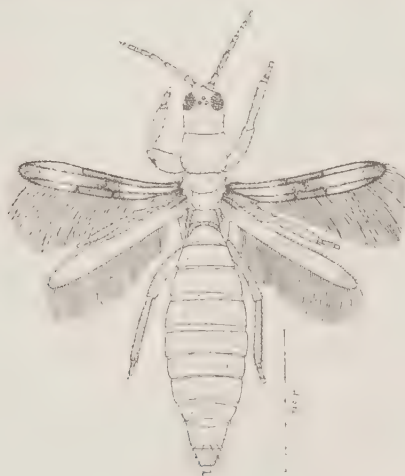


Fig. 1. *Desmothrips davidsoni*, sp. n., ovigerous female.

Desmothrips davidsoni, sp. n.

Holotype ♀ (fig. 1). General body colour concolorous dark brown; red subcuticular colour lies scattered in various parts. All antennal segments dark brown, except III, of which the cuticle is almost colourless, but the contents are pale yellow, and the apex of II and the base of IV, which are shaded with pale yellow. Eyes black. Ocelli with dark reddish-brown crescents. Maxillary and labial palpi dark brown. Legs dark brown except for a shade of yellowish brown along the inner side of the fore tibia. Fore wing almost colourless except for three separate light brown patches, the first very small lying at the extreme base and extending half way into the alula, the second lying across the middle of the wing, and the third at the apex. The veins are clearly visible, but lightly coloured. Hind wing almost colourless,

with a very pale brownish patch across the middle and another at the apex. Ovipositor yellowish brown. Hairs on the body, legs, antennal segments I–II, the dark patches of the forewings and the posterior fringing hairs of fore and hind wings, brown. Other hairs on antennae and wings almost colourless.

Measurements. Length (width): antennal segments, I 32 (35), II 52 (32); III 121 (26), IV 95 (26), V 52 (23), VI 32 (22), VII 35 (21), VIII 20 (15), IX 15 (7); total length of antenna 446; sensory area of III 87 (3), IV 75 (3), V 23 (3), VI 20 (3); head 198 (205?); ocelli 18; eye 72 (42?); mouth-cone 200? (150?); maxillary palp segments I 57 (14), II 9 (8), III 6 (7), IV 6 (7), V 6 (7), VI 6 (6), VII 10 (6); labial palp segments I 3 (10), II 9 (8), III 6 (6), IV 10 (5); prothorax 200 (220?); pterothorax 270 (300); fore wing 840 (102 at apex of alula, 138 where widest across second colourless patch), length of colourless and brown areas 300, 210, 180, 150; hind wing 810 (96); abdomen distended 1260 (420); length of abdominal segments VIII 78, IX 100, X 78, XI 30; ovipositor 396; total length of insect 1920. Length of hairs: longest hairs of posterior fringe of fore wing 350; on abdominal segments II 14, IV 14, VIII 34, IX 116, X 120, XI 46.

Head with its dorsal surface ornamented with many confluent, transverse, dark striae and a number of short hairs. Cheeks almost parallel. Eyes not projecting, but with the dorsal margin rounded and the ventral portion of the eye gradually contracting and extending almost to the mouth-cone. The facets of moderate size and the hairs few and minute. Ocelli placed between the eyes at the apices of an equilateral triangle. Each lateral ocellus separated from the eye by the diameter of its lens.

Antennae 9-segmented, inserted in front below the vertex of the head and closely approximated. Segment I rectangular in outline; II barrel-shaped but more constricted at the base; III elongated, cylindrical, with a short pedicel, and on the outer ventral surface with a long sensory area with waving parallel sides; IV elongated, cylindrical, expanding slightly towards the apex, and with a long sensory area on the outer ventral surface. The waving sensory area has parallel sides and curves sharply dorsad at the apex, where it half encircles the segment. Segments V–IX closely united and tapering from VII to IX, which ends fairly bluntly. Each segment V–VIII bears one or more elongated sensory areas. Segments I–II bear a few fairly strong, dark hairs, and the other segments bear many small, almost colourless hairs.

Prothorax almost rectangular but with its posterior angles rounded. The pronotum bears about fifty small scattered hairs. Mesonotum with distinct, dark, confluent, transverse striae. Metanotum with reticulate dark striae. Legs elongated, fairly slender, covered with many small hairs and with a pair of short spines at the apex of each tibia, as well as a row of six stiff hairs on the inner surface near the apex of the third tibia. The fore coxa bears three stiff hairs on its anterior surface and a similar hair on its posterior surface. The hairs on the other coxae smaller. The fore femur somewhat enlarged and the second segment of the fore tarsus bears a small hook-like process. Fore wing with a marginal vein, two longitudinal and five cross-veins, and one oblique vein, which serves the alula and unites with the free end of the marginal vein. Short hairs lie evenly scattered along the anterior marginal, the two long and the oblique veins. The posterior fringe starts at about the middle of the first colourless area and is longest at the second colourless area, and at the rounded apex of the wing it dwindles into the elongated hairs of the anterior marginal vein. Alula with two long apical and one short basal hair. Hind wing with a small median, basal vein. The posterior fringe at the apex of the wing becomes continuous with a row of delicate hairs bordering the anterior margin for about two-thirds of its length.

Abdomen of elongate ovoid shape. Few small hairs are borne by all the segments, but IX has dorsally a posterior marginal row of four long hairs and a long hair at

either side and four similar hairs on the ventral surface; X bears dorsally a median transverse row of four long hairs.

Allotype ♂: Coloration like that of female, but a little paler.

Measurements: antennal segments, I 30 (37), II 52 (29), III 110 (23), IV 98 (26), V 46 (23), VI 37 (20), VII 40 (20), VIII 26 (14), IX 14 (6); total length of antenna 468; sensory area III 87 (3), IV 80 (3), V 34 (3); head 150 (168); ocelli 14; eyes 72 (40); mouth-cone 156 (126); maxillary palp segments I 36 (15), II 7 (8), III 5 (8), IV 4 (8), V 5 (8), VI 4 (7), VII 6 (6); labial palp segments I 3 (7), II 9 (6), III 7 (5), IV 8 (4); prothorax 162 (180); pterothorax 204 (258); fore wing 750 (84, 108); length of colourless and brown areas 270, 180, 168, 132; hind wing 700 (?); abdomen 900 (240); length of abdominal segments I tergum 160 (120), VIII 60, IX 84, X 60, XI 30; genitalia 150; total length of insect 1500. Length of hairs: longest hairs of posterior fringe of fore wing 340, on abdominal segments II 9, IV 9, VIII 17-26, IX 46-72, X 90-110, XI 43.

Morphology like that of female. Urotergum I is strongly chitinised and triangular in shape. Abdominal segment IX bears dorsally at its posterior margin a row of four long hairs, and ventrally a pair of long hairs near the posterior margin besides a pair of longer hairs more ventrad. Segment X bears a pair of long hairs dorsally and a pair of shorter hairs ventrally.

Described from 1 ♀ holotype and 2 ♀ paratypes and 1 ♂ allotype. The holotype, allotype and 1 paratype have been deposited in the British Museum, and the other paratype returned to the Waite Institute.

All the females were ovigerous, bearing 1-4 eggs, 390 (120) in size. I consider that the three females belong to the same species, but they show some variation which may be described thus: Length (width): antennal segment III 121-136, IV 95-116, VI 32-48, VII 35-40, sensory areas on III 87-100, IV 75-87, V 23-30, VI 20-23; maxillary palp segment I 54-66; pterothorax 252-270; fore wing 840-978 with corresponding difference in the relative sizes of the colourless and brown areas; hind wing 810-900 (96-114); abdominal segment VIII 78-90, IX 100-116, X 78-90; total length of insect 1836-1950. In one paratype antennal segment III is almost colourless owing to its contents having lost their pale yellow colour. In the other paratype one maxillary palp is 7- and the other 8-segmented. The first maxillary palp segment in both sexes is obliquely ringed by three pale lines, which suggest that this segment has been derived by the fusion of four equal segments.

***Desmothrips elegans*, sp. n.**

Holotype ♀ (fig. 2). General body colour concolorous dark brown with red subcuticular colour. All antennal segments dark brown, except III of which the cuticle is yellowish shaded with light brown near the apex and the contents are pale brownish yellow. I and II are darker than the rest. The apex of II is shaded with yellow and IV has a narrow pale ring just above its base. Eyes black. Ocelli with brown crescents. Maxillary and labial palps dark brown. Legs dark brown except for a shade of yellow down the middle of the fore tibia and continued into its tarsus, making it paler than the others. Fore wing almost colourless except for three light brown patches, the first very small lying at the extreme base of the wing and extending half way into the alula, the second at the middle, the third at the apex and connected with the second by the brown anterior marginal vein and a brown band between the second long vein and the posterior margin of the wing. The veins clearly visible but lightly coloured. Hind wing almost colourless, but with three very pale brown areas placed like those of the fore wing. Ovipositor yellowish brown. Hairs on body, legs, antennal segments I and II, the dark patches of the fore wings and the posterior fringing hairs of fore and hind wings, brown. Other hairs on antennae and wings almost colourless.

Measurements. Length (width): antennal segment I 30 (37), II 52 (32), III 100 (26), IV 87 (26), V 43 (26), VI 31 (24), VII 26 (22), VIII 15 (14), IX 14 (9); total length of antenna 425; sensory area III 72 (3), IV 63 (3), V 23 (3), VI 20 (3); head 138 (192); ocelli 14; eyes 78 (54); mouth-cone 240 (168); maxillary palp segments I 65 (14); II 8 (10), III 7 (9), IV 7 (7), V 7 (7), VI 7 (7), VII 8 (6); labial palp segments I 3 (9), II 18 (8), III 7 (7), IV 14 (6); prothorax 180 (220); pterothorax 300 (330); fore wing 1020 (144, 174); length of colourless and brown areas 390, 270, 180, 180; hind wing 960 (120); abdomen 990 (450); length of abdominal segments VIII 90, IX 132, X 78, XI 36; ovipositor 420; total length of insect 1650. Length of hairs: longest hairs of posterior fringe of fore wing 400; on abdominal segments II 15, IV 20, VIII 17-42, IX 174, X 174, XI 65.

Morphology like that of *davidsoni*, from which *elegans* is easily separated by the following characters: the colour of antennal segment III; the shortness of III-V; the sensory areas of III-IV are almost straight; the head is shorter and less produced in front of the eyes; the banding of the fore wings; and the longer hairs on abdominal segments IX-X.



Fig. 2. *Desmothrips elegans*, sp. n., female.

Described from 1 ♀ holotype and 4 ♀♀ paratypes. The holotype and 1 paratype have been deposited in the British Museum, and 2 paratypes have been returned to the Waite Institute.

Three of the paratypes were ovigerous, bearing 1-2 eggs, reaching 390 (100) in size. The following variation was noticed in the females: Length (width): antennal segment III 87-100, IV 72-87, V 43-46; sensory areas on III 52-72, IV 43-63; maxillary palp segment I 50-65; pterothorax 240-300; fore wing 930-1050 with corresponding differences in the relative sizes of colourless and brown areas; hind wing 830-990; abdominal segment VIII 78-90, IX 114-138, X 72-78; total length of insect 1290 contracted, 2040 distended. The first segment of the maxillary palp seems to be ringed with three pale lines as in *davidsoni*.

Amongst other characters *davidsoni* is distinguished from *bagnalli*, Karny, *comparabilis*, Priesner, *obsoletus*, Bagnall, by the marking of the fore wing; from *australis*, Bagnall, by the colour of antennal segment III ♀, ♂; from *propinquus*, Bagnall, by the colour of antennal segment III ♀; from *tenuicornis*, Bagnall, which it most resembles, in the proportionate length of antennal segments III-IX and in the

banding of the fore wings. *D. elegans* is distinguished from *australis*, *propinquus*, and *tenuicornis* by the marking of the fore wings; from *obsoletus* in the colour of antennal segments III–IV; from *bagnalli* in the marking of the fore wing; but there is the possibility that *bagnalli*, *comparabilis* and *elegans* will prove to be varieties of a variable species, *bagnalli*. *D. comparabilis* was described from a male and *bagnalli* from a damaged female.

Family THRIPIDAE.

Limothrips cerealium, Haliday. 28 ♀♀, 21 ♂♂, typical dark specimens in tubes labelled, viii. and x. 1929.

Limothrips angulicornis, Jablonowski. 6 ♀♀, 2 ♂♂, x. 1929.

Pseudanaphothrips achaetus (Bagnall). 3 ♀♀, x. 1929.

Thrips tabaci, Lindeman. 7 ♀♀, x. 1929.

Suborder TUBULIFERA.

Family PHLOETHRIPIDAE.

Haplothrips melanocerus, Bagnall. 4 ♀♀, x. 1929.

Haplothrips victoriensis, Bagnall. 2 ♀♀, 1 ♂, x. 1929.



Fig. 3. *Oedemothrips propinquus*, Bagnall, male.

Oedemothrips propinquus, Bagnall. The finding of the hitherto unknown male settles this species in its genus, which Bagnall queried in 1916 (Ann. Mag. Nat. Hist. (8) xvii, pp. 408–409) and 1918 (ibid. (9) i, p. 214). Four ♀♀ were found; two with the ♂ during v. 1929, and each of the other two separately during x. 1929. Though they conform closely to the description (1916) of the single specimen of *propinquus* from Victoria, Australia, the ♀♀ vary amongst themselves in some characters which make them intermediate between *propinquus* and var. *breviceps*, Bagnall, described from Nelson, New Zealand (1924, A.M.N.H. (9) xiv, pp. 634–635). The general body colour is reddish brown and the variation lies in this becoming gradually almost black behind the fifth abdominal segment or even behind the head. The coloration is probably connected with age. Total length varied from 1500 (partly contracted) to 1980 (partly distended). Head length 186, width greatest just behind eyes 234, least at base 198, or, in another specimen, 192 (234, 204); therefore, in these two specimens it varies 0.79–0.82 times as long as broad, with the cheeks distinctly convergent posteriorly; tube 168 (96 at base, 42 at apex), or, in another specimen, 174 (102, 45).

Male (fig. 3). Head and thorax reddish brown with the abdomen dark brown and

darkest from the third segment, but with the apical third of the tube paler. The colour is due to the light or dark brown cuticle covering a reddish brown subcuticular colour. Antennal segment I light yellowish brown, II slightly darker; III yellow brown with the basal half clear yellow, IV and V brown with the basal thirds yellowish, VI-VIII totally brown. Eyes almost black. Mouth-cone and ends of tarsi tipped with dark brown. Maxillary and labial palps brown. Legs yellowish shaded with light grey-brown. Hairs yellowish brown but pale on the antennae and legs.

Measurements. Length (width): antennal segments I 36 (42), II 42 (33), III 72 (30), IV 72 (30), V 66 (30), VI 60 (28), VII 42 (24), VIII 30 (12); total length of antenna 430; head 174 (198, 168); eye 66 (33); mouth-cone 114 (156 at base); maxillary palp segments I 12 (12), II 32 (9); labial palp segments I 12 (12), II 12 (5); prothorax 180 (186, 306); pterothorax 150 (288); fore leg femur 210 (108), tibia 174 (42), tarsus 72 (30), inner tarsal claw 30 (28), outer claw 15 (8); abdomen 960 (408); total length of insect 1480. Length of hairs: longest hairs on antennae 42, interocular 50, postocular 72, prothoracic anterior 35, lateral 60, posterior inner 63, outer 58, on abdominal segments II 20-58, IV 20-58, VIII 90, IX 80, at end of tube 33-110.

Morphology, like that of female, from which the male differs in the comparative length and width of the head, prothorax and fore legs, in which the femora are more expanded and the first tarsal segment bears a strong claw on the inside besides a smaller one on the outside. In the female the first tarsal segment seems to bear the single tarsal claw, and in both sexes each second tarsal segment of the middle and hind legs bears a single small claw placed cephalad. Most of the body hairs are cylindrical, tapering slightly, and with the tip almost colourless and somewhat flattened.

Type slide of male and two slides of females deposited in the British Museum and one female returned to the Waite Institute.

ON THE POST-EMBRYONIC DEVELOPMENT OF THE FEMALE LAC INSECT, *LACCIFER LACCA*, KERR (HEM-COCCIDAE).*

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(PLATE XX.)

Introduction.

The following investigation of the development of *Laccifer lacca*, Kerr, was carried out in the Department of Zoology, Lucknow University, under the supervision of Professor K. N. Bahl, D.Sc., D.Ph., to whom I am much indebted for the extensive facilities enjoyed in his laboratory.

The literature on this subject is very scanty, consisting at best of a few stray observations or remarks. Imms' account† of the metamorphosis of the female covers less than half a page and embodies no systematised or detailed description of the post-embryonic development. Green, in his "Coccidae of Ceylon" (1922), does not attempt it, and most of his remarks refer exclusively to the form of the female test (the resinous cell). In his account of *Tachardia conchiferata*, after describing the form of the nymphal test, Green says, "I have been unable to follow out the subsequent transformations." About the best extant account of the post-embryonic development of the female lac insect is that of MacGillivray.‡ His description, however, is faulty and not substantiated by a detailed embryological and microscopical study of the process. Apparently, he had no opportunity of studying this insect himself. Negi.§ in a paper on the life-history of *Laccifer lacca*, has recorded some observations on the metamorphosis of the female, which however refer exclusively to the external characters.

Life-cycle of the Lac Insect.

The lac insect of the genus *Laccifer* has two life-cycles in a year. The larvae on swarming out in June immediately search for a suitable place on the host-plant, where they settle down for life and commence the secretion of resin. Towards the beginning or middle of August the males emerge out of the resinous cells within which they were housed till now, and immediately set out in quest of the females, dying after copulation. The females are viviparous and give birth to larvae about the beginning or middle of October, when a second cycle takes place. The males of this generation appear about the middle or end of February, and die after fertilising the females, the emergence of the larvae taking place towards the beginning or middle of June. The hot-weather generation, or "baisakhi crop" as it is popularly called, requires only about four months for the completion of its life-cycle, whereas the cold-weather generation, or the "kartiki crop," needs about eight months. The males of the hot-weather generation are apterous, but both alate and apterous ones occur in the cold-weather generation.

* This paper formed part of a thesis approved for the degree of Doctor of Science in the Lucknow University.

† Imms, A. D. & Chatterjee, N. C. "On the structure and biology of *Tachardia lacca*, Kerr, with observations on certain insects predaceous or parasitic upon it."—Ind. For. Mem., For. Zool. Ser., iii, pt. 1, 1915.

‡ MacGillivray, A. D. "The Coccidae," 1921.

§ Negi, P. S. "A contribution to the life-history of the lac insect *Laccifer lacca*."—Bull. Entom. Res., xix, 1929, pp. 327-341.

Structure of the Larva.

The first stage larva is a minute crimson-red creature of extremely active habits. It is ovate in form, being broadest in the region of the thorax, and tapering posteriorly. There are no pronounced demarcations between the head, thorax and abdomen. The head carries a pair of antennae, a pair of ocellanae, and ventrally the mouth-parts. The antennae are composed of six segments including the basal one. The mouth-parts are on the same plan as those of the female, but the rostrum is greatly elongated, the loop reaching up to the 5th or 6th abdominal segment. On the ventral side of the thorax are situated two pairs of spiracular openings; in association with the anterior pair are found sieve-like brachial plates, which are wanting in the case of the posterior spiracles. The abdomen is made up of 8-9 segments, of which the last few are telescopic. The last segment of the abdomen forms the anal ring, which carries a pair of greatly elongated setae in addition to three shorter pairs arranged round the anal opening. The lac-glands are unicellular, with prominent nuclei and very delicate ducts, all being similar, since no specialisation so far has set in. The gut has the same essential form and structure as that of the male lac insect described by me in another paper; the oesophagus, ventriculus, proximal and distal intestines, Malpighian tubes, colon, colon caecum and the rectum can be identified without difficulty. Salivary glands are also present, like two "bunches of grapes" on either side. The nervous system consists of the cerebral ganglion and the ventral ganglion, which are connected by a pair of connectives, with the oesophagus passing between them.

Secretion of the Resinous Cell.*

Secretion of the lac commences soon after the fixation of the larva, but is confined to the venter only. Two or three days after the settlement a resinous disc is noticeable beneath the larva, the deposition of resin being more copious towards the caudal end than elsewhere, which results in the upward curvature of the caudal segments of the abdomen (fig. 1, *b, c*). This deposit is further augmented by additional secretion, thus increasing the tilt of the tail (fig. 1, *d*); this occupies a week and a half, after which the resinous secretion begins to invade the dorsum also. Two bands of resin appear on the dorsum, thereby marking it into three subequal parts (fig. 1, *d*). One of these is located just behind the brachial plates associated with the anterior pair of spiracles in the region of the fourth segment; the other being five segments ahead of the caudal end of the body. Up to this stage (*i.e.*, 16 days after fixation) the secretion of resin on the dorsal surface is confined only to these two transverse bands, though it is copiously deposited on the ventral side. After the appearance of the transverse resinous bands, dots of resin appear on the rest of the dorsum also, which by coalescing subsequently cover up the dorsum with a thin smear of resin. The anterior portion enlarges cephalad; the middle portion enlarges laterad either way, becoming bulbous in outline; while the last section remains more or less unaffected. Viewed from above, the resinous cell of this stage consists of one anterior, one caudal, and two lateral lobes. The cephalic and lateral lobes subsequently constrict into two, thereby giving rise to six lobes (fig. 1, *f, g*). Later on, the irregularities of outline disappear and the cell assumes a rounded shape (fig. 1, *h*). The formation of the female cell is completed in three weeks and a half after the establishment of the larva on the host-plant. In all stages of growth and development the resinous cell is an exact replica of the female lac insect which it encloses. The division of the cell into three parts, its subsequent lobed appearance, and the final disappearance of the irregularities are all visible indications of the corresponding changes undergone by the metamorphosing larva. The vault of the cell is always pierced by three openings, one for the anal tubercle, the other two for the brachia

* The observations are based upon the *baisakhī* life-cycle of the insect.

of the respective sides, the anal opening being the largest. The aperture for the anal tubercle is distinct from the second larval stage onwards; the other two are not quite so pronounced up to the third larval stage, but their position can be judged from the pencils of wax that issue from them.

Post-embryonic Development.

First stage larva. This has been described above and is essentially the same as that of the male. The first ecdysis takes place one month and seven days after the larval settlement on the host-plant. The rejected cuticular covering separates from the body, but may remain inside the cell. If cells of this stage be dissolved in spirit, cuticular covers are often found inside them, either in shreds or more or less incomplete, usually at the anterior end, which indicates that the rupture is effected at the cephalic extremity. A more detailed account of this stage has been given elsewhere.

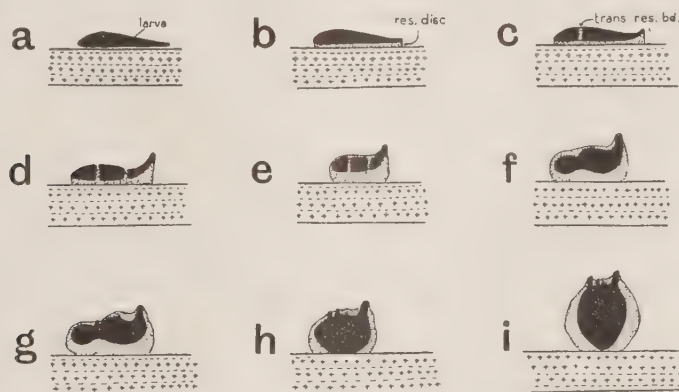


Fig. 1. Diagram to illustrate the stages in the deposition and growth of the resinous cell of the female lac insect: the female is shown black, and the resinous cell dotted.

Second stage larva. This is not only more swollen in form than the first stage larva and limbless, but is characterised by certain features which enable us to differentiate it from the corresponding second stage larva of the male lac insect. The development of the generative organ is deferred in the case of the female to the third stage, whilst in the male the testicular masses can be recognised in the second stage larva.

Along with these changes, the caudal segments of the abdomen become upturned on account of the copious deposit of lac-resin under them (fig. 1, *d*) and a groove appears at the anterior end, somewhat behind the brachial plates, in the region of the fourth segment, constricting off the cephalic zone from the rest of the body. Furthermore, the anterior spiracles are found migrating dorsad from their normal position on the sternum of the thorax (fig. 3, *b-e*), and in doing so they shift along the groove referred to above. A similar groove appears five segments ahead of the caudal end of the abdomen, so that the body of the advanced second stage larva becomes marked off into three regions (fig. 1, *d*). The posterior spiracles retain their normal position. The upturned terminal segments form the beginning of the anal tubercle of the adult female, which bears terminally the anal ring and the ten anal ring setae located on six plates bearing numerous anacerores. The cuticular periphery of the anal ring is fringed by an outer whorl of setae and spines. The lac-glands of the second stage larva are all alike.

At about this stage, three months after larval settlement on the host-plant, the second stage larva moults.

Third stage larva. By this time the female is completely enclosed within a resinous cell (fig. 1, *f, g*), which, at this stage, has a characteristic form. Viewed from above it consists of one anterior, one caudal, and two lateral lobes. The resinous test at this stage possesses three apertures, two at the caudal limits of the cephalic lobe and one at the anal end through which waxy filaments are given out. The third stage larva completely fills the cell and is similarly lobed, the larva having the same appearance as the resinous cell investing it (fig. 5, *c*). The anterior spiracles with the associated brachial plates are found lying at the dorsal limits of the anterior groove supported on short brachia, having by this time shifted completely upwards (fig. 3, *f, g*). A new structure, the dorsal spine, has now appeared and is recognizable at this stage as a blunt conical projection placed in the middle of the triangular area enclosed by the anal tubercle and the brachia (fig. 3, *g*). In sections, it is seen to be an outgrowth of the cuticle accompanied by the hypodermis. The lac-glands of the first stage larva were all alike, but now some of them have aggregated into three areas along the margins of the cephalic and the lateral lobes (fig. 5, *b, c*). These at a later stage will give rise to the large flask-shaped glands which are restricted to the six serpentine areas at the aboral end of the female lac insect. The nervous system is composed of an anterior kidney-shaped cerebral ganglion, a ventral ganglionic mass and the connectives. The connectives lie immediately above the chitinous framework of the mouth, and the flexed cerebral ganglion occupies the greater part of the cephalic lobe (fig. 8, *b-d*). The rudiment of the anal tubercle (*i.e.*, the flexed penultimate segments of the body) enlarges, as does its opening. The longitudinal tergal and sternal muscles are in their usual relative positions, but the tergo-sternals at the extreme end, owing to the upward bend, are abnormally inserted (fig. 7, *c, f*). In the meanwhile the female generative rudiment has also differentiated, and in the sections of this stage the united oviducts seem to open on one side of the anal tubercle. Wax-glands in association with brachial plates and round the anal opening are present at this stage as in the previous one.

Adult female. By the third and last moult, which occurs after four months, the female larva passes into the adult form. In contrast with the foregoing stage, the adult shows a more marked growth of the brachia, which have become chimney-like projections, bearing apically the brachial plates, and the spiracles are in a groove on their outer sides (fig. 3, *h, i*). The dorsal spine now consists of a basal pedicel and a terminal spine (figs. 3, *h, i*; 4, *e*). The spine is only a thickly chitinised portion of the terminal part of the original protuberance. The three lobes of the foregoing stage have, by a further constriction, given rise to six lobes, so that the adult female possesses two anterior cephalic lobes and four lateral lobes besides the median caudal lobe (fig. 5, *d*). The nervous system is very much in the same condition as before, but the tergo-sternal muscles of the caudal segments of the abdomen being no longer able to withstand the strain have given way, and consequently have become disorganised (fig. 7, *d-f*). Similarly, the longitudinal tergal muscles, which come within the sphere of influence of the developing dorsal spine, become disorganised and lose their identity (fig. 7, *f*). The three arcs of lac-glands associated equatorially with the lobes have also become marked off into six glandular tracts (fig. 5, *d*). At this stage the differentiation of the two types of lac-glands is complete. To the first type belong minute unicellular glands, with a slender duct and a small nucleus, which are distributed everywhere under the integument, except in the six marginal or equatorial areas already referred to (fig. 5, *c, d*). To the second type belong the flask-shaped glands, having prominent nuclei, nucleoli, and wide ducts, which are restricted in their distribution to the six equatorial areas (fig. 5, *c, d*). Such is the adult form of the female lac insect before gestation.

Important changes take place after fertilisation. The ovary begins to develop fast, and, since the development of the young takes place within the mother, embryo-sacs are formed as outgrowths of the ovarian wall. The lobed appearance of the females is gradually lost owing to the growth of the ovary and the embryo-sacs within, which smooth out the irregularities of the body by inflating it. *Pari passu*, the resinous cell also loses its lobed appearance and becomes rounded off. The brachia in the meanwhile become greatly elongated, carrying the spiracular opening at their bases (fig. 3, *i*). The posterior spiracles, however, retain their position on the ventral side close to the oral end of the insect, and are surrounded by oval chitinated discs. On account of the distortion and remoulding of the body, the brachia and the anal tubercle with the enclosed dorsal spine are approximated together at what is now the aboral end of the insect (fig. 3, *j*). The brachia and the anal tubercle at this stage occupy, roughly speaking, the three angles of an isosceles triangle in the centre of which the dorsal spine is placed. Accompanying these external changes, the internal organs of the female also deviate considerably from the normal type. It has already been pointed out that the brachia and anal tubercle get approximated together at the aboral end of the insect, and consequently the dorsal insertion of the tergo-sternal muscles is compacted into the area enclosed by them (fig. 7, *f-h*). Ventrally, however, they retain their insertion. Again, owing to the aforesaid upheavals in structure and the appearance of a new structure, the dorsal spine, the longitudinal tergal muscles become disorganised within the triangular zone enclosed by the brachia and the anal tubercle (fig. 7, *e* & *f*). The sternal longitudinal muscles are, however, able to survive the shock to some extent and are consequently recognizable as such (fig. 7, *d-h*). They retain traces of their segmental marks, of which 4-5 can be made out on the integument. The gut, though structurally the same, is better displayed owing to the availability of greater space in the interior of the female body (fig. 6, *f*). Of all structures the nervous system suffers the most during the gestational period. Not being able to keep pace with the enormous strain brought to bear upon it by the morphological upheavals, the nervous system ruptures at its weak point (the position of the connectives), so that the cerebral and the massive ventral ganglia become disconnected (fig. 8, *e*), the latter moving to the base of the anal tubercle, where it lies alongside the terminal part of the gut. Similarly, the free cerebral ganglion is carried away from its normal position entangled with the Malpighian tubes to the aboral end of the insect (fig. 8, *f*).

Change of Form in the Female Lac Insect.

From a typical oligopod larva the female lac insect develops into a pyriform sac, in which all surface boundaries and limitations have practically been obliterated, except for the traces of segmentation on the anal tubercle, the antennae, and the sternal longitudinal muscles.

Previous workers on this insect have often used the terms "anterior" and "posterior." They regard the area E F A as constituting the posterior end of the female and the area B C D (fig. 2) as the anterior one. If the facts of the post-embryonic and gestational development be borne in mind, it will be apparent that, strictly speaking, these terms are not applicable to these areas. Although all surface limitations on the body have become obliterated, yet to one familiar with the sequence of events the limitations on the surface of the body are still recognizable empirically. In the light of the foregoing account of the post-embryonic development the area A B C D (fig. 2) is the ventral surface of the body, whilst the area D E F A constitutes the dorsal surface. The anal tubercle represents the five penultimate segments of the abdomen of the larva. The brachia are new acquisitions, and the triangular

area enclosed by the brachia and the anal tubercle represents two thoracic and four abdominal segments.

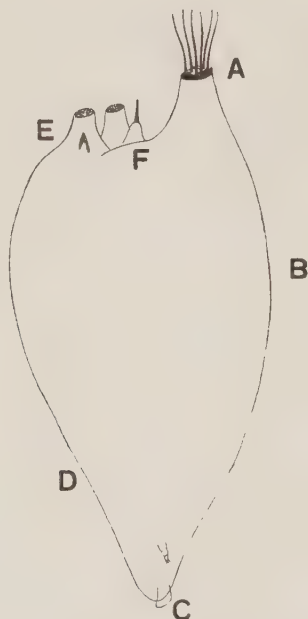


Fig. 2. Diagram of female lac insect showing the change in the orientation of the parts.

Migration of the Spiracles.

The first stage larva has two pairs of spiracular openings on the sternum of the thorax (fig. 3, *a*). The anterior pair of openings is situated in front of the first pair of legs with sieve-like brachial plates in association with it. The posterior pair of openings is situated between the first and the second pair of legs, but has no brachial plates. When the first moult is about to take place a groove appears just close to the brachial plates of the anterior spiracles, and these with the brachial plates begin to migrate dorsally along this groove (fig. 3, *b-d*).

After the first moult the brachial plates are found on the dorsal side of the second stage larva flush with the surface of the body (fig. 3, *e*). Later, the cuticle surrounding these brachial plates and the spiracles constricts off, forming tubular evaginations carrying the brachial plates at their summit and the spiracular openings at the sides. In the third stage larva (fig. 3, *f, g*) these tubular evaginations are more pronounced than in the second stage larva. When the third moult takes place and the larva changes into the adult, the tubular evaginations—or more properly speaking the brachia—are elevated appreciably above the body surface (fig. 3, *h*). During the gestational growth of the female the brachia become very much elongated and approximated to the anal tubercle, owing to the remoulding of the body. The posterior pair of spiracles retain their ventral position till the second larval stage, but when the surface limitations are obliterated, partly in the third larval stage and completely during the gestational period, the posterior spiracles come to lie at the oral end of the insect (fig. 3, *j*).

The anterior spiracular openings have not infrequently been referred to as the "posterior spiracles." This was evidently due to their position at the so-called posterior end of the insect. Green was probably the first observer to rectify this error and to point out that a reversal in the position of the spiracles occurs during metamorphosis—the anterior ones becoming posterior in position and the posterior ones anterior. My observations validate Green's remarks, but I desire to point out that strictly speaking the terms "anterior" and "posterior" are not applicable to the adult female lac insect and should, therefore, be discarded, and in their place the

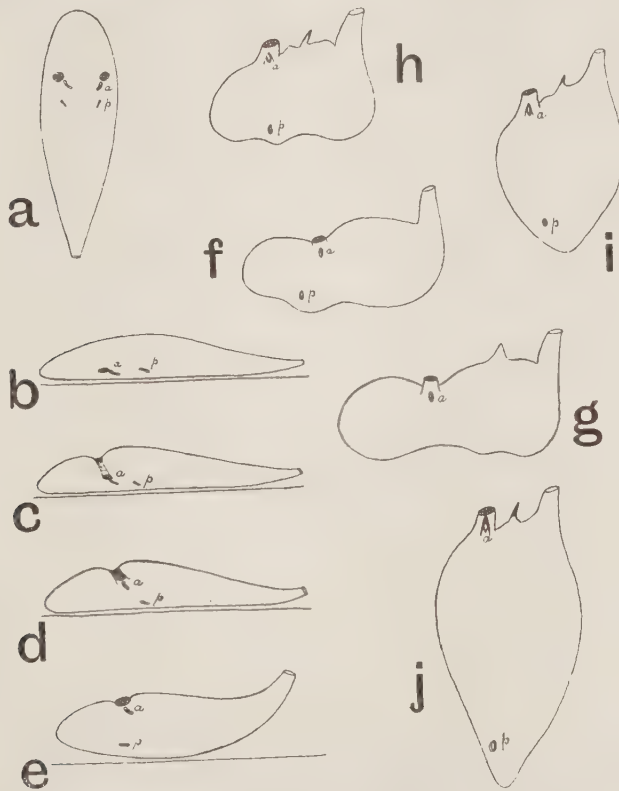


Fig. 3. Stages in the migration of the anterior spiracles during the growth of the female lac insect and the development of the brachia.

terms "oral" and "aboral" should be employed. I have shown above that the so-called "posterior end" of the female is not, in fact, its posterior end. Strictly speaking, it is a new enclosure of a composite nature.

Secretion of Wax.

The structure and distribution of the wax glands of the adult female and larva have already been dealt with by me in other communications on this subject. Suffice it to say here that the wax glands of the first stage larva are confined in their distribution to the lower surface of the brachial plates and also round the anal opening.

In a surface view, the wax glands are seen forming a semicircular disc underneath the brachial plates. The wax filaments form a very attractive feature of the second stage larva, in which they issue out of the crater of the brachial plates and the anal ring also. Three pencils of wax threads are invariably recognisable at this stage, but the pencils are by no means thick because the deposition of wax is not sufficiently vigorous.

The waxy filaments become more numerous in the third stage, and at the time of the appearance of the males the filaments of the female are fairly abundant. After the visits of the male the secretion of wax becomes active, so much so that the females become, more or less, completely enveloped in a waxy felt and obscured from view (Plate XX). The tree on which the lac insect is growing looks as though it were

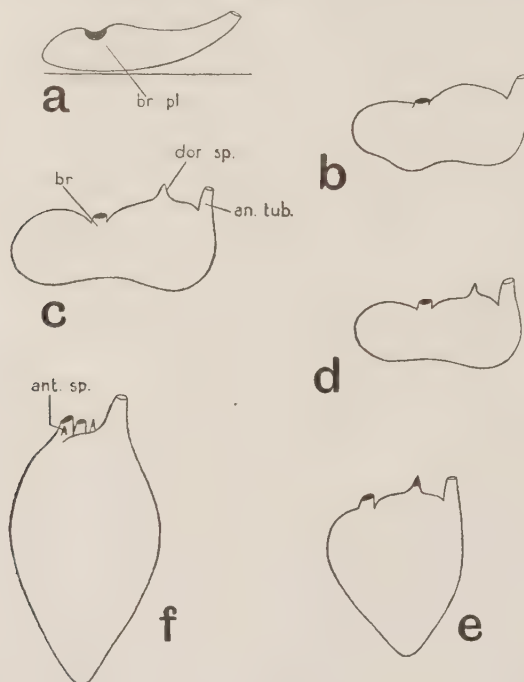


Fig. 4. Diagrammatic representation of the stages in the differentiation of the external form of the female lac insect during its post-embryonic development.

covered with a coat of white bloom (Plate XX), and wax is so copiously secreted that it even comes off in shreds. Soon, however, depression sets in and the secretion of wax wanes, until it ceases at the close of the gestational period.

Differentiation of the Lac-Glands.

The lac-glands of the first stage larva are all alike and are indifferently distributed everywhere under the body cuticle. They are unicellular with a prominent nucleus, a short duct and a comparatively large fundus. The first indication of differentiation is noticeable in the second stage larva, in the first instance by the upward deflection of the penultimate segments of the abdomen, which is brought about by the excessive deposit of resin by pluricellular glands of this region and the aggregation of some unicellular glands along the marginal line. I have not been able to follow the history

of these pluricellular glands in the subsequent stages of growth. In the third stage larva three equatorial arcs of lac-glands are noticeable at the anterior cephalic and lateral margins of the body respectively (fig. 5, *b, c*). In the early adult female, these three arcs break up into six areas, of which two are derived from the anterior cephalic lobe and two from each of the lateral lobes (fig. 5, *d*). The rest of the body is dotted with lac-glands of the diffuse type, like those of the first stage larva. The lac-glands of the early adult female are, therefore, of two kinds. To the first type belong the pluricellular groups of glands which are confined in their distribution to the perivaginal pore clusters on the venter. To the second type belong glands which

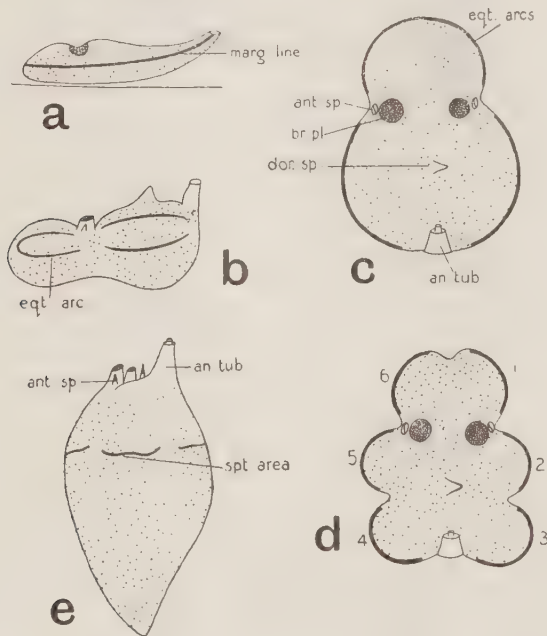


Fig. 5. Diagrams illustrating the differentiation and arrangement of the lac-glands.

are essentially of a unicellular nature, some being flask-shaped, with enlarged fundus, prominent nuclei, and wide necks. These are, however, very restricted in their distribution, being confined only to the six serpentine areas at the aboral end of the insect (fig. 5, *e*). The rest of the body is studded with unicellular glands possessing a small fundus, slender ducts and small nuclei.

Disposition of the Gut.

In the first stage larva, which is considerably compressed dorso-ventrally, the disposition of the gut and its component parts is as indicated in fig. 6, *a, b*. At this stage the Malpighian tubes lie alongside the colon-rectum. In the second stage larva the arrangement is practically the same, but the gut is better displayed on account of the availability of greater space in the interior of the insect (fig. 6, *c*). In the advanced third stage larva, which is more or less saccular in outline, the free ends of the Malpighian tubes and the blind end of the recurrent intestine are directed

towards the anal tubercle, and the recurrent intestine sweeps a circle inside the body cavity. The pharynx and oesophagus are freer than before on account of the relief afforded to them by the lift accorded to the rest of the gut. Such is the disposition of the gut at fertilisation (fig. 6, *d*), after which the female grows in size, and ultimately the free ends of the Malpighian tubes and the blind limb of the recurrent

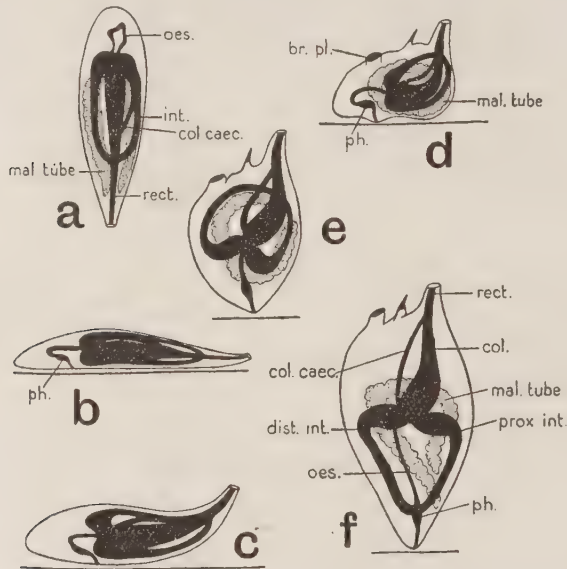


Fig. 6. Diagrams illustrating the disposition of the gut of the female lac insect, especially before and after gestation.

intestine are directed towards the oral end of the insect, which means that transposition through an angle of 180° has been effected (fig. 6, *f*).

Development of the Muscular System of the Adult.

The first stage larva possess 7-8 double pairs (fig. 7, *c*) of tergo-sternal muscles and the same number of longitudinal tergal and sternal muscles. In the second larval stage, the caudal segments of the abdomen become curved upwards on account of the excessive deposit of lac under them. When this happens the longitudinal tergals become relaxed on account of the concavity thus caused, whilst the longitudinal sternal muscles are stretched (fig. 7, *b*). In the third stage larva, the anal tubercle (the caudal abdominal segments) enlarges and the tergo-sternal muscles belonging to this region, not being able to withstand the pull, give way (fig. 7, *d-e*). The more anterior tergo-sternals (those belonging to the middle region), however, persist. At this stage, the dorsal spine makes its appearance, and the longitudinal tergal muscles coming within the zone of its influence are adversely affected (fig. 7, *d-f*). During the period of gestational growth the brachia and the anal tubercle become approximated and consequently the dorsal insertion of the tergo-sternal muscles, belonging to the middle section, is compacted into the limited space between them (fig. 7, *g-h*). The longitudinal sternal muscles are able to survive these changes, since they lie on the

ventral side, which is not affected (fig. 7, *e, f, h*). The entire sequence of these changes and the ultimate disposition of the muscles in an old adult female are represented by the accompanying figures.

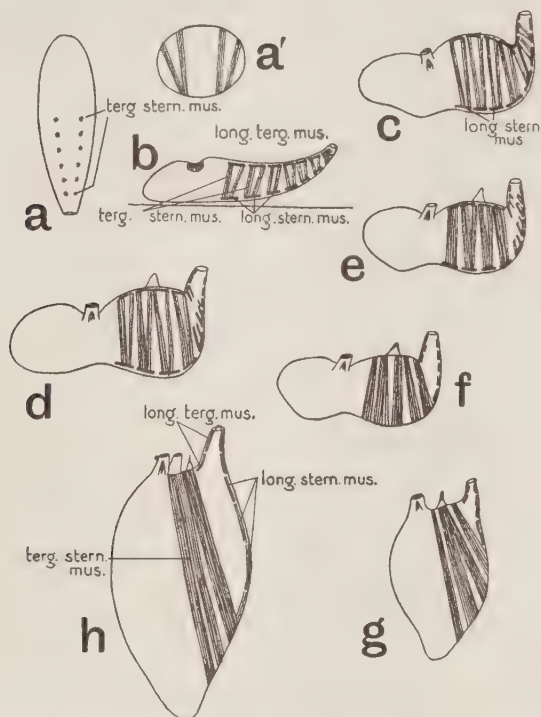


Fig. 7. Diagrammatic representation of the changes affecting the muscular system of the female lac insect during development.

Changes in the Nervous System.

In the first stage larva the nervous system consists of a kidney-shaped, fairly large cerebral ganglion, and a ventral massive ganglion. The two are united by a pair of connectives, which embrace the oesophagus between them, and the ventral ganglion gives off a number of nervures to the appendages and internal organs. In sections, the connectives are found overlying the chitinous framework of the mouth-parts. The cortex of the cerebral and ventral thoracic ganglia is numerously studded with deeply staining nuclei; and the medulla is made up of a homogeneous substance from which nuclei are absent. In sections, the ventral ganglion shows itself to be composed of 6-7 ganglia fused together. These probably represent the three infra-oesophageal, three thoracic and the first abdominal. The nervous systems of the second and the third stage larvae do not differ in any noteworthy respect from that of the first stage larva. It is only during the gestational growth of the female that a catastrophe overtakes it. It has already been pointed out that considerable growth in length and size takes place in the female lac insect during its gestational period. The nervous system is, therefore, subjected to considerable strain. Not being able to withstand this it ruptures at its weak point, the position

of the connectives, so that the cerebral and the thoracico-abdominal ganglia become disconnected (fig. 8, *e*). The freed cerebral ganglion is carried away from its normal position, entangled with the Malpighian tubes, to the aboral end of the insect, where it may be detected lying close to the distal limb of the intestine or the Malpighian tubes (fig. 8, *f*). Similarly, the thoracico-abdominal ganglion is carried away by the gut, and comes to lie at the base of the anal tubercle close to the terminal parts of

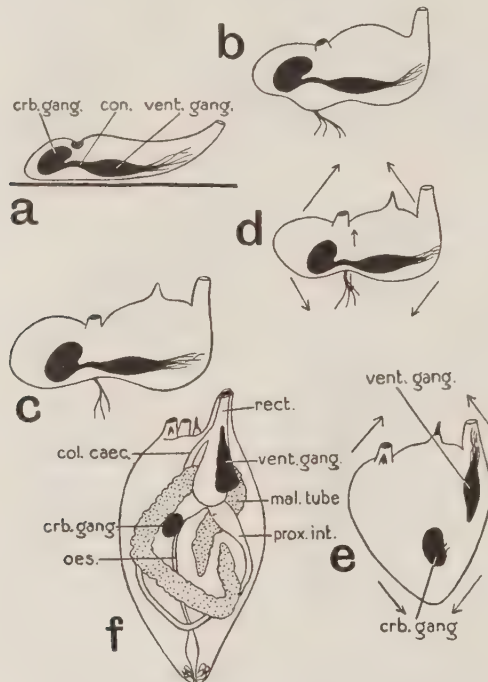


Fig. 8. Diagrams illustrating the changes in the nervous system during development.

the gut. The rectal ganglion of the adult female is, therefore, the thoracico-abdominal of the larva, and the one lying close to the Malpighian tubes or intestine is, in fact, the cerebral ganglion of the same.

Lettering of the Text-figures.

An. tub.	...	...	...	...	=	Anal tubercle.
Ant. sp.	...	...	...	...	=	Anterior spiracle.
Br. ...	...	...	...	...	=	Brachium.
Br. pl.	...	...	...	...	=	Brachial plate.
Crb. gang.	...	...	...	...	=	Cerebral ganglion.
Con. ...	...	...	...	...	=	Connective.
Col. ...	...	...	...	...	=	Colon.
Col. caec.	...	...	...	...	=	Colon caecum.
Dist. int.	...	...	...	...	=	Distal intestine.
Dor. sp.	...	...	...	...	=	Dorsal spine.
Eqt. arc.	...	...	...	...	=	Equatorial arc.

Int. ...	...	...	...	...	=	Intestine.
Long. stern. mus.	...	...	...	...	=	Longitudinal sternal muscles.
Long. terg. mus.	...	...	...	...	=	Longitudinal tergal muscles.
Mal. tube	...	...	...	...	=	Malpighian tube.
Marg. line	...	...	...	...	=	Marginal line.
Oes. ...	...	...	...	...	=	Oesophagus.
Ph. ...	...	...	...	...	=	Pharynx.
Prox. int.	...	...	...	...	=	Proximal intestine.
Rect.	...	...	...	...	=	Rectum.
Res. disc	...	...	...	...	=	Resinous disc.
Sal. gl.	...	...	...	...	=	Salivary gland.
Spt. area	...	...	...	...	=	Serpentine area.
Trans. res. bd.	...	...	...	...	=	Transverse resinous band.
Terg. stern. mus.	...	...	...	...	=	Tergo-sternal muscle.
Vent. gang.	...	...	...	...	=	Ventral ganglion.



Lac on *Zizyphus jujuba*, showing secretion of white waxy filaments.

STUDIES ON THE GALLERIES OF THE BARK-BEETLES.

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The galleries of the bark-beetles are as a rule such characteristic features of the different species that sometimes these are more easily recognised by the shape of their galleries than by their own structure, as, for example, in the case of the two pine-beetles, *Blastophagus piniperda* and *B. minor*, in which the distinguishing features of the insects cannot be discerned without the help of a good pocket-lens. But, on the other hand, the galleries of many species are subject to a certain amount of variation and show typical modifications which are responses to various external factors, such as the size of the trunk or of the branches, the thickness of the bark, and the orientation of the trunk, *viz.*, whether the tree is standing or felled.

The galleries of the bark-beetles are divided into several groups according to the number and direction of the egg-galleries, etc. Hitherto the curious fact, that one species has a single transverse egg-gallery, whereas another closely related species has a longitudinal one, has been accepted as something established, no one questioning why this is so. In my opinion the time is now ripe to enter into a more detailed survey of the many and varied features displayed by the galleries of bark-beetles. The following is intended as a contribution to a discussion regarding these important and interesting problems.

The fundamental difference between the oviposition of the bark-beetles and of other species, the larvae of which live in the cambium of trees, is that the former themselves burrow under the bark. Even the pine-weevils excavate pockets in the cambium, depositing several eggs in each pocket, but remain themselves on the surface of the bark, using their long snouts as instruments for excavating the egg-pockets.

In some genera of bark-beetles the eggs are laid in clusters in an irregular cavity (*Cryphalus*, *Dendroctonus micans*), but as a rule special egg-galleries are excavated, along the walls of which egg-pockets are made, generally one for each egg, which latter is surrounded either by shavings of fibres, which is the prevailing method, or isolated by a common mortar-like substance which closes and completely hides the mouths of all the egg-pockets (*Scolytus*).

It is evidently of the utmost importance to the welfare of the brood that the egg-galleries should be clear of wood-dust. Otherwise it is impossible to explain those modifications in the directions of the egg-galleries which will be dealt with later and which cannot conceivably have any other purpose than to facilitate or make possible the removal of wood-dust from the egg-galleries. The importance of the egg-galleries being kept empty becomes also evident when we consider that by so doing the bark-beetles expose themselves and their brood to dangers from their numerous enemies whose entrance into the galleries is thus made easy. The advantages accruing from this habit must therefore of necessity be far greater than the disadvantages.

What is the advantage of cleaning the egg-galleries, is, however, a question very difficult to answer. It may be assumed that it is either essential to repeated sexual intercourse, which, in some species at least, is necessary for the fertilisation of all the eggs, or that it is necessary for ventilation, including the maintenance of a proper temperature and moisture, and preventing the growth of mould in the galleries. The difficulty in choosing between these (and other) explanations lies in the fact that the other arrangements made by those species that do not keep their egg-galleries clean serve these purposes equally well. *Ips acuminatus*, for instance (fig. 1. b),

has its egg-galleries filled with a closely packed mass of fine wood-dust, which naturally prevents the beetles from wandering to and fro in the galleries. This remarkable exception to the rule elsewhere observed in the genus *Ips* is obviously due at least partly to the fact that this species is polygamous, and that the egg-galleries are numerous, sometimes 10–12, and rather long, owing to the great distance, about 1 cm., between the egg-pockets. This makes it impossible for a single male to perform his customary task in the genus *Ips*, viz., to sweep the galleries with the help of the females and to transport the wood-dust outside. But in the same species we find along the egg-galleries numerous passages through the bark, which are not funnel-shaped and narrowing outwards, as the typical air-passages do, but are of even width throughout and large enough to allow the beetles to pass through them, a performance which has also been observed.

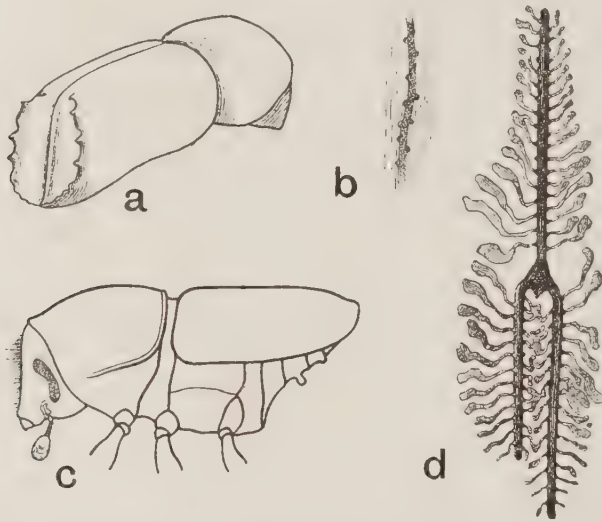


Fig. 1. *a*, male of *Orthotomicus proximus*, showing the deep posterior declivity of the elytra; *b*, portion of egg-gallery of *Ips acuminatus*, with egg-pockets, filled with a densely packed mass of wood-dust and excrement; *c*, male of *Scolytus ratzeburgi*, showing ventral declivity of abdomen; *d*, gallery system of *Ips typographus*, in standing tree, with one upper egg-gallery and two lower ones.

This example seems at least indirectly to favour the suggestion that the cleaning of the galleries has as its primary purpose to enable the sexes to meet repeatedly. It is true that in some species, such as *Hylastes ater* and *H. cunicularius*, which keep their galleries clean, only one fertilisation takes place. But this is no evidence against the validity of my suggestion, because it is easy to conceive that the instinct of cleaning the egg-galleries has become so fixed in the bark-beetles that they still adhere to it even if the original cause for it does not exist any more.

The possibility that the same instinct has originated in response to the necessity of ventilating the galleries can of course not be rejected, but at the same time we must bear in mind that the free access of air to the eggs does not seem to be such a conspicuous feature in the economy of the bark- or wood-boring insects as to warrant the very difficult work performed by the bark-beetles in keeping their galleries clean.

In any case it is evident that many important features in bark-beetles, as well as many of the modifications of their galleries, cannot be understood unless viewed in the light of the all-important necessity of keeping the galleries clean.

Before entering into a discussion regarding the typical shape and the modifications of the galleries, it is necessary to consider some points of the external morphology of the bark-beetles, which are intimately connected with the excavating of the galleries and the transport of the detritus. From the point of view of the external morphological features connected with this work the bark-beetles may conveniently be arranged in four groups.

1. Most highly specialised are the genera *Ips*, *Orthotomicus* and *Pityogenes*, in which the posterior declivity of the elytra is excavated (fig. 1, *a*), and more so in the males than in the females. These forms, and only these, have galleries of such a pattern that at least one gallery runs vertically downwards from the nuptial chamber, which necessitates that the dust produced during the excavation must be transported upwards, in some instances as far as 20 cm. (*Ips sexdentatus*). The close connection between the shape of, for instance, *Ips typographus* and its pattern of galleries, one of which runs downwards (fig. 1, *d*), is very obvious. Without the posterior excavation, which serves as a shovel, it would be impossible to excavate and clean such a gallery, a feat which involves the overcoming of the force of gravity.

Granted this, the question arises: "How do other species, not possessing such an excavation of the elytra, manage to get rid of the detritus?" It is not possible to give an answer to this question as regards all the bark-beetles, because the methods employed in burrowing the galleries and disposing of the dust have hitherto been only little investigated. A brief survey of the external morphology of the bark-beetles, coupled with the few observations available concerning their burrowing and cleaning activities, reveals, however, that they are specialised in several directions for this purpose.

2. As regards the SCOLYTINI one might feel inclined to regard their peculiar shape, with the ventral excavation of the abdomen (fig. 1, *c*), as corresponding with the dorsal excavation of the genera *Ips* and *Orthotomicus*, and serving the same purpose, the transport of the detritus. This possibility must be reckoned with, even if, according to Shevirev's views, the shape of the abdomen primarily serves the purpose of facilitating sexual intercourse.

But the SCOLYTINI have also other structures which must be useful for burrowing purposes, viz., the broad flattened tibiae which are of the same shape as in such typical fossorial insects as the dung-beetles. Still, the SCOLYTINI are not highly enough specialised to be able to make galleries downwards, as *Ips* does.

3. In other bark-beetles we find two other structures, sometimes in the same genus. These are: a rather dense clothing of perpendicular hairs, especially on the elytra, and a sharp collar, directed forward, at the base of the elytra (fig. 2, *a*, *b*). In *Blastophagus* and *Dendroctonus micans* we find both structures, in *Polygraphus* and *Carphoborus* we find only the collar. But in those genera which have the elytra excavated posteriorly there is not a trace of such a collar-shaped structure (fig. 2, *c*, *d*).

The dense clothing of hairs undoubtedly enables its bearers effectively to brush the galleries clean by moving backwards in them, and the sharp collar probably acts as a kind of scraper. As a matter of fact, one very often finds wood-dust in the space between the base of the prothorax and the collar.

4. Finally, there are many genera which to all appearance have no structural adaptations, but which nevertheless manage to keep their galleries clean, such as *Hylurgops* and *Hylastes*.

This survey is of necessity very brief, since so few observations have been made dealing with the structural adaptations of bark-beetles to their burrowing activities.

The different orientation of the galleries of the same species in standing and felled trees is a feature which also bears evidence of the great importance of the galleries being kept clean.

It is easy to observe these modifications in some of our most common species. When, for instance, *Blastophagus minor* attacks a standing tree, the short entrance

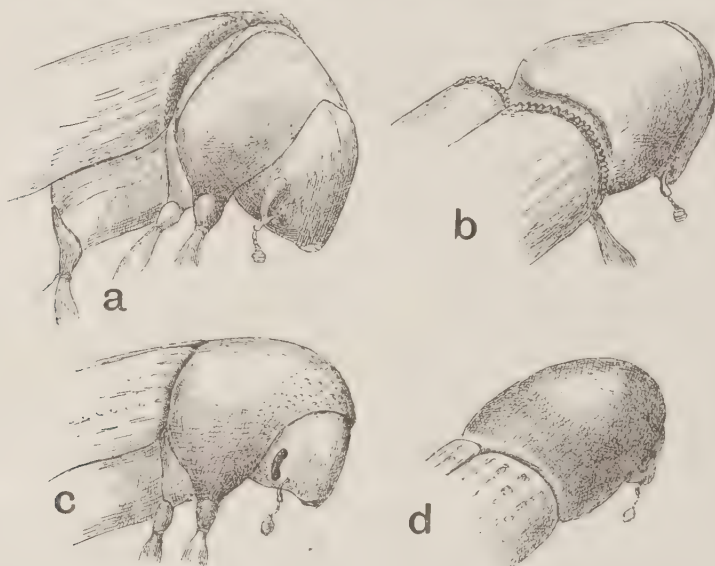


Fig. 2. *a, b*, anterior and posterior view of *Dendroctonus micans*, showing collar-shaped anterior edge of elytra ; *c, d*, *Ips* sp., without the collar-shaped structure.

gallery that branches off in the two transverse galleries always points downwards (fig. 3, *a*), evidently to act as an outlet for the dust that is pushed out through it. But whenever the same species attacks a felled tree, in which case it breeds on the underside of the trunk, the direction of the galleries seems to be more irregular

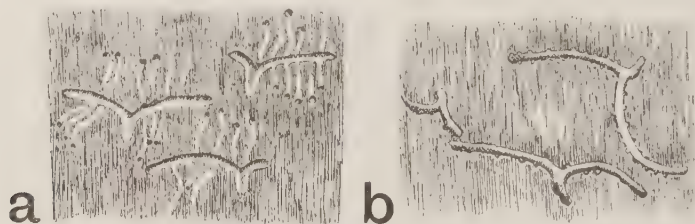


Fig. 3. Egg-galleries of *Blastophagus minor* in: *a*, standing tree ; *b*, underside of fallen tree.

(fig 3, *b*). On closer inspection we always find the entrance gallery pointing downwards.

This difference in the orientation of the galleries of *B. minor* is so constant that it enables us to tell with absolute certainty whether the tree was attacked before or after it was cut.

In *B. piniperda* we notice corresponding modifications. After the short funnel-shaped burrow which forms the entrance through the bark follows an almost spherically enlarged part and then the proper egg-gallery. In standing trees these parts form a straight or almost straight line, the gallery always pointing upwards (fig. 4, *b*). But when the beetles breed in fallen trees the funnel-shaped part is always vertical, whereas the egg-gallery is horizontal, pointing either to the left or to the right (fig. 4, *a*).



Fig. 4. Egg-gallery of *Blastophagus piniperda* in: *a*, felled tree; *b*, standing tree.

Even in the nuptial chambers of those species whose shape enables them to overcome the force of gravity, such as *Ips typographus*, we find some corresponding features which vary according to the orientation of the tree and serve the purpose of facilitating the transport of the wood-dust from the galleries (fig. 5). Examining the shape of the nuptial chamber of *I. typographus* in a standing tree, we notice that whenever there are only two egg-galleries, one upwards, the other downwards, they do not run in a straight line, with the nuptial chamber forming a straight connection

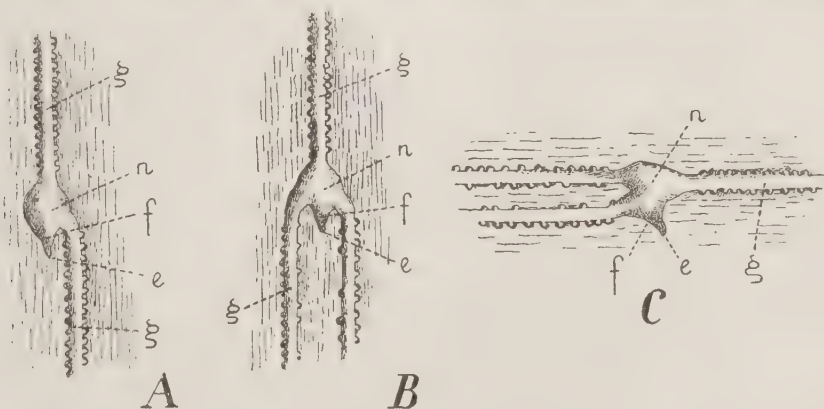


Fig. 5. Central part of gallery of *Ips typographus* in: A, standing tree; B, standing tree, with three egg-galleries; C, felled tree, with three egg-galleries.—*g*, egg-gallery; *n*, nuptial chamber; *f*, funnel-shaped part of nuptial chamber; *e*, entrance-gallery to nuptial chamber acting as mouth through which detritus is ejected.

between them, but one of the galleries is always a little to the right or to the left side of the other. If the lower gallery is to the left it does not start from the bottom of the nuptial chamber, but from about half-way up on its left side, so that from the mouth of the egg-gallery the wall of the nuptial chamber slopes downwards. At the lowest point of the nuptial chamber we always find the entrance tunnel, acting as an outlet for the dust. The mouth of the upper gallery, on the other hand, is directly above the outlet from the nuptial chamber. This shape of the nuptial chamber and the

position of the mouth of the egg-galleries offer two very important and obvious advantages to the bark-beetles. For one thing, the detritus from the upper gallery does not drop into the mouth of the lower gallery but into the funnel-shaped part of the nuptial chamber, the outlet of which is the entrance gallery. Moreover, as soon as the detritus from the lower gallery is brought up to its mouth, it falls down to the right side towards the outlet.

When there are two lower egg-galleries the lowest part of the nuptial chamber is between them, directly below the mouth of the upper gallery, which arrangement offers the same advantages as the other one.

In felled trees, on the other hand, the entrance funnel always forms approximately a right angle with the egg-galleries, so that use can be made of the force of the gravity.

From these observations it is evident that the direction of the egg-galleries is not subject to any marked modifications according to the orientation of the tree. But the funnel-shaped entrance always points downwards in order to act as an outlet for the detritus.

In many other species that breed in both standing and felled trees we find corresponding modifications serving the same purpose of facilitating the cleaning of the egg-galleries.

But there are not a few species which one *never* finds in felled trees. For the discussion of this interesting problem I choose two species, *Pityophthorus micrographus* and *Cryphalus abietis*. This may be due either to the fact that they do not breed close to the ground, but only far up in the crown of the trees, or to the impossibility of keeping the galleries and nuptial chamber clean from wood-dust in felled trees. The first alternative seems to apply to *Pityophthorus micrographus*, which attacks the upper part of spruces, where the bark is thin. The second alternative seems to apply to *Cryphalus abietis*, which typically breeds in stunted spruces in close, not properly thinned stands, and in these occurs almost down to the ground.

During recent years I have been able to make a few observations which throw some light on this problem. At the experimental park, Simlångsdalen, of the Royal Swedish Institute of Experimental Forestry, in a 25-year-old spruce stand, a lot of spruce-tops were left on the ground after the thinning operations. It was impossible to find in these any species except *Pityogenes chalcographus*. But, fortunately, one of the tops had been left leaning on one of the remaining spruces in an almost upright position. In this top, but only in this, *Cryphalus abietis* was breeding. *This observation shows that the upright position of the top, not the distance from the ground, was the factor determining the choice of the bark-beetle.*

In the summer of 1929 an experiment was made with *Pityophthorus micrographus*. A few spruce-tops were cut in the spring, some of them being left on the ground, some being fastened to other spruces and thus being kept in an upright position. The former only were attacked by *Pityogenes chalcographus*, the latter were attacked by both *Polygraphus poligraphus* and *P. micrographus*.

How is one to explain this remarkable fact that something, seemingly so unimportant as the vertical or horizontal position of the spruce-top, determines the choice of the breeding-place of these two species? The explanation is, in my opinion, not far away. It is the same supreme necessity of getting rid of the wood-dust in the nuptial chamber and the egg-galleries, which caused the modification of the galleries already discussed. Let us see how the solving of this problem is accomplished in these two species. In both cases it is not a gallery which must be emptied, but a cavity, which is a far more difficult task—because it is always easier to clean a gallery where the walls closely surround the bark-beetle, thus preventing the detritus from escaping when the beetles move along. In *Cryphalus abietis* the cavity serves

the double purpose of acting as a nuptial chamber and as an egg-gallery. In *P. micrographus* it serves only as nuptial chamber, special egg-galleries existing, which are, however, not empty but filled with wood-dust. In both species the chamber is comparatively large in comparison with the bark-beetles.

It is evident that so long as these cavities, in their initial stage, are tunnel-shaped, there is no difficulty in getting rid of the wood-dust, even if the cavity is horizontal, because it can always be pushed out by the bark-beetles. But as soon as the cavity is enlarged, insurmountable difficulties present themselves. If, for instance, *Cryphalus* should try to push out the shavings in such a cavity without help of the force of gravity, the shavings would simply escape to both sides. This is the reason, then, why these two and many other species never breed in felled trees, but only in standing ones.

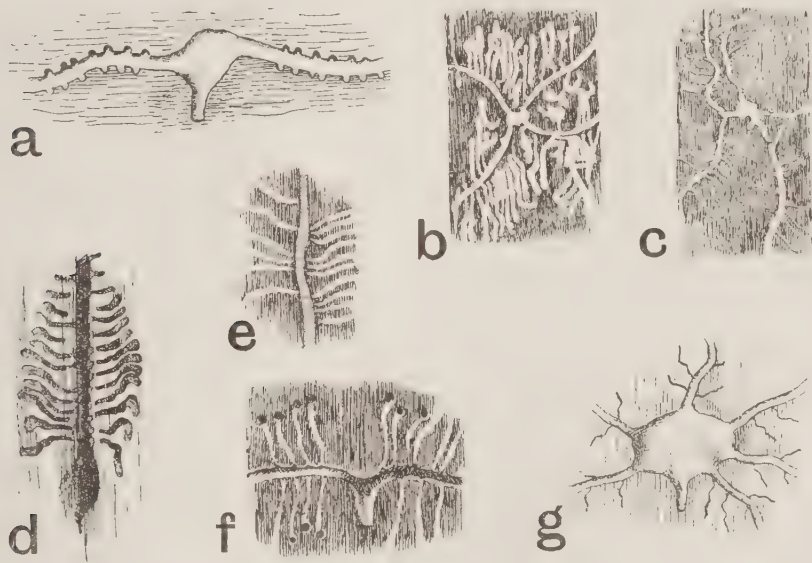


Fig. 6. *a*, nuptial chamber of *Orthotomicus proximus*; *b*, *c*, gallery-systems of, respectively, *Pityophthorus pityographus*, with the larval tunnels longitudinally and fairly deeply engraved in the surface of the wood, and of *Pityophthorus micrographus*, with the larval tunnels running in all directions in the bark; *d*, upper part of egg-gallery of *Ips typographus*, showing the increasingly less pronounced curvature of the younger larval tunnels; *e*, *f*, portion of gallery of, respectively, *Blastophagus piniperda*, to show the superficiality of the tunnels and egg-pockets, and of *B. minor*, to show the deep tunnels and egg-pockets; *g*, nuptial chamber of *Carphoborus cholodkovskyi*, showing its great size.

On the other hand, there is one species which, at least in Sweden, has hitherto only been found in felled trees, viz., *Orthotomicus proximus*. This species has generally two longitudinal egg-galleries, which are always clear of wood-dust. This is easily accomplished by the beetle, which, like all the members of this genus, has the hind end of the elytra cut off at almost a right angle and excavated, with surrounding ridges and teeth, the whole structure acting as a very efficient shovel. Besides this, from the nuptial chamber there always runs at a right angle to the egg-galleries the entrance tunnel (fig. 6, *a*), which is at least gently sloping downwards and acts as an outlet for the wood-dust.

This short survey of some facts relative to the galleries of the bark-beetles has emphasised the all-important feature in their biology that the galleries must be emptied of wood-dust. This explains the modifications in the direction of the entrance tunnel, as well as the fact that some species never breed in felled trees.

We are now prepared to enter into a discussion regarding the different patterns of the galleries, which have hitherto been accepted as a matter of course, without any attempt at explaining the reason for the differences.

It is well known that the pattern of the galleries even of very closely related species may be quite different, which shows that these patterns, although very specific, cannot be used as indicators of the relationships between the species. It is evident that the pattern is greatly influenced by some external factors, as we shall see below.

Let us start this investigation with two very closely related species that have different galleries, *Pityophthorus micrographus*, L., and *P. pityographus*, Rtt., which are, as a matter of fact, so closely related that they have been confused until lately, when the northern form was found by Saalas in Finland and described by Eggers as *fennicus*, until Spessivtseff proved it to be the same as *micrographus*, L., and gave the name *pityographus* to the Central European form, formerly wrongly supposed to be *micrographus*, L.

In both species the pattern of the egg-galleries is star-shaped, but in *pityographus* the larval tunnels run longitudinally, strictly parallel to one another, whereas in *micrographus* they are quite irregular as to their direction (fig. 6, b, c). What can be the reason for this remarkable difference in two so closely related species? A closer examination of the larval tunnels reveals the fact that in *pityographus* they furrow the surface of the wood fairly deep from the very start, while in *micrographus* the larval tunnels run entirely in the inner bark. Perhaps the reason for the different direction of the larval tunnels of these two species is that the larvae are able to burrow in the surface of the wood only by gnawing off the fibres transversely, whereas it is of no importance in which direction they gnaw in the soft inner bark. If that is the true interpretation of the different direction of the larval tunnels, one would expect to find longitudinal tunnels also in other species where they furrow the surface of the wood deeply, but no special orientation when the tunnels only furrow the wood superficially or not at all, running in the inner bark. This is actually the case. In *Blastophagus pini-perda*, for instance, the larval tunnels are very superficial and more or less transverse, whereas in the closely related species *B. minor* the larval tunnels are longitudinal and furrow the wood deeply at least in the distal two-thirds.

If we make a survey of the 40 Swedish bark-beetles that do not burrow in the wood or live in such small twigs that the pattern of the galleries and tunnels is influenced more by the small space than by anything else, we find that in 27.5 per cent. of them the rule holds good that the larval tunnels are deeply excavated in the surface of the wood and longitudinal, in 67.5 per cent. they are irregular and do not furrow the wood; only in 5 per cent., viz., the two species *Carphoborus chlodkovskyi* and *Ips acuminatus*, does this rule not apply.

Some of the larger ECCOPTOGASTERINI also form an exception to this rule, probably because their mandibles are so strong that they are able to gnaw into the wood in any direction.

It seems, therefore, to be the rule that there is a distinct relation between the direction of the larval tunnels and the depth to which they are engraved in the surface of the wood. Deeply engraved larval tunnels are longitudinal, while superficial ones, or those which are excavated entirely in the bark, may run in any direction.

When discussing the orientation of the larval tunnels we must, however, not forget that the larvae are arranged in a certain way already by the direction and shape of the egg-pockets, which depend on the direction of the egg-galleries.

What factors determine the direction of the egg-galleries? And how are we to explain at all the remarkable and unique gallery-systems of the bark-beetles? In order to understand this we must bear in mind that the bark-beetles differ from most other insects in that they are under the strict necessity of utilising to the utmost the space available. If amongst other free-living insects overcrowding threatens on a plant or a branch of a tree, the supernumerary insects are as a rule easily able to emigrate to other plants.

But the larvae of bark-beetles cannot emigrate, surrounded as they are on all sides by the walls of the tunnels they have excavated. They can only bend the gallery in another direction. And at the same time the egg-pockets are often very close together in the egg-galleries, which are frequently themselves very crowded, the number of larvae in a given area being often very large. There is, therefore, every reason to suppose that unless the larvae were already arranged in the egg-stage in such a way as to ensure the larval galleries running parallel to one another, great mortality would follow owing to the fact that one larva encountering another lying crosswise in front of it would certainly kill the latter.

This danger is, at least to a great extent, obviated by the linear arrangement of the eggs in the pockets of the egg-galleries. As a matter of fact, the larval tunnels as a rule run strictly parallel with one another. The question remains, however, to be answered whether this feature is due entirely to the orderly arrangement of the eggs or is brought about partly by the larvae having the ability of finding out the safest direction where there is least competition of food.

At all events, it is evident that one factor, *viz.*, the degree of decomposition or dryness displayed by the surrounding parts of the cambium, must guide the larvae into the proper direction. Whenever, for instance, two egg-galleries of the greater pine-beetle (*Blastophagus piniperda*) happen to be rather close together we notice that those larval tunnels which start in the area between the galleries very soon turn either to the right or to the left in order to reach more suitable regions.

It may be, then, that the larvae starting from the same egg-gallery are materially assisted in finding the proper direction by their slightly older comrades to the right or to the left as the case may be. Because, owing to the work involved in the successive excavating of the egg-gallery and egg-pockets, the eggs never hatch contemporaneously, but one after the other, the last one making its tunnel at a certain distance from the next older one. It is very easy to ascertain, at least in *Ips typographus*, for instance, that the earliest larval tunnels often do not run so straight as the others, bending in a curve towards the side of the nuptial chamber, and that the following two or three tunnels have the same curve, only a little less pronounced, the curve finally disappearing in the latest tunnels (fig. 6, *d*).

To sum up, it seems fairly evident that the gallery-systems of bark-beetles are a means of ensuring the larval tunnels running as parallel as possible, thus obviating the danger of the larvae encountering one another with fatal results.

In this way the most economical exploitation of a certain area is achieved, combined with the greatest safety. Of the successful results attained by this method many species bear witness, for instance, *Leperisinus fraxini*, the galleries of which often so completely cover the surface of the ash-trunk that hardly a square millimetre is left, and not a single egg-gallery or larval tunnel interferes with any of its neighbours.

The necessity of utilising as economically as possible the quantity of food available, and the need of obviating or lessening the danger imminent to a dense population, are therefore, in my opinion, the two fundamental factors to which the gallery-systems of the bark-beetles owe their origin.

The orientation of the egg-galleries is, therefore, the primary factor on which the direction of the larval tunnels mainly depends. It remains, then, to investigate

which factors may conceivably influence the orientation of the egg-galleries. For this discussion we may conveniently reckon only with two different types of egg-galleries, the longitudinal ones and those which are more or less transverse. Why are the egg-galleries in some species longitudinal, in others transverse? Does their direction correspond to the depth to which they are engraved in the surface of the wood, as in the larval tunnels?

Comparing two closely related species, *Blastophagus piniperda* and *B. minor*, we find that the egg-gallery of the former is longitudinal and furrows the surface of the wood very little, in the latter the two egg-galleries are transverse and deeply engraved in the surface of the wood. Is there any relation between these two features? It cannot be explained on the ground that it would be more easy for the beetle to gnaw deeply into the wood in a transverse direction, because there are also longitudinal galleries which are fairly deep, such as those made by *Hylurgops glabratus*.

In my opinion we find the solution of the riddle if we investigate closely how the egg-pockets are excavated in these two types of egg-galleries. In *B. minor* the egg-pockets are cut out in the wood almost to the same level as the egg-gallery, (fig. 6, f), whereas in *B. piniperda* no distinct egg-pockets are visible on the surface of

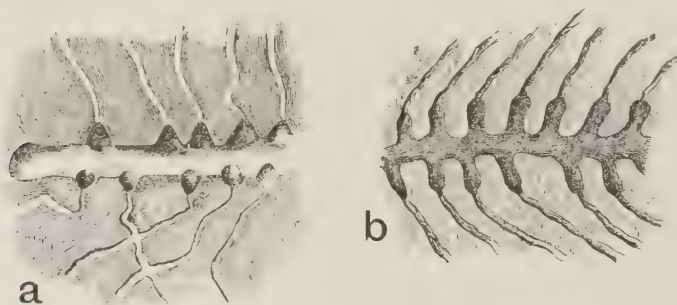


Fig. 7. Portion of deep transverse egg-gallery, with deep egg-pockets, of: a, *Xylechinus pilosus*; b, *Pityogenes chalcographus*.

the wood (fig. 6, e). If we examine the egg-pockets of other bark-beetles we find quite similar conditions. Referring to the two species of *Pityogenes* already mentioned, *P. micrographus* and *P. ptyographus*, we notice that in the latter, the egg-galleries of which are either oblique or transverse and cut deeply into the surface of the wood, the egg-pockets are quite as deep as the galleries and the larval tunnels strictly longitudinal and deep. In *P. micrographus*, on the other hand, the larval galleries of which run in all directions, the egg-galleries as well as the egg-pockets are in the bark.

The same condition, that egg-pockets excavated deeply in the wood are correlated with more or less transverse deep egg-galleries, applies also to *Phthorophloeus spinulosus*, *Xylechinus pilosus* (fig. 7, a), *Taphrorychus bicolor*, and *Pityogenes chalcographus* (fig. 7, b); whereas in most of the species with longitudinal egg-galleries the egg-pockets are either very superficial or only furrow the surface of the wood very little.

We arrive, then, at the conclusion that in those species in which the food of the larva consists to a great extent of wood, the larval tunnels are as a rule longitudinal and correlated with deep egg-pockets in more or less transverse, deep egg-galleries.

It is not possible, without further investigations and experiments, to arrive at any deeper insight into the fundamental factors influencing the behaviour of bark-beetles

when excavating their nuptial chambers, egg-galleries, etc. The following general statements regarding their activities may, however, be safely formulated, at least tentatively.

1. The all-important necessity of keeping the nuptial chamber and the egg-galleries clean from wood-dust throws light on some structural features of bark-beetles as well as on some modifications of their burrowing instincts commonly found.

2. We do not know whether the cleaning only serves the purpose of making repeated sexual intercourse possible or also is essential for the ventilation of the eggs, including the maintenance of proper temperature and humidity, or preventing the growth of mould.

3. The shape and pattern of the galleries are closely related to the shape of beetles.

4. The most highly specialised bark-beetles, the genera *Ips*, *Orthotomicus* and *Pityogenes*, have the elytra more or less excavated for the purpose of acting as shovels. It is almost exclusively in these genera that we find galleries running downwards, a feature that depends on the ability to transport the detritus upwards.

5. It is possible that the ventral declivity of the SCOLYTINI serves the same purpose, the transport of detritus.

6. In other genera, such as *Blastophagus* and *Dendroctonus*, the body is clothed with perpendicular hairs and acts as a kind of brush, and the base of the elytra projects forwards and forms a collar-shaped ridge. Both structures probably serve as tools in cleaning the galleries. In some genera, such as *Polygraphus* and *Carphoborus*, which have only the collar, particles of wood are often found in the cavity between the collar and the prothorax.

7. Several genera have no such conspicuous features, but are nevertheless able to clean their galleries, such as *Hylurgops* and *Hylastes*.

8. The galleries show some distinct modifications, depending on whether they are excavated in standing or felled trees. The general direction of the egg-galleries is, however, not or only very slightly influenced, but only the part of the nuptial chamber (when there is one) or the short entrance tunnel through which the beetles have penetrated under the bark. This part always points downwards, because it is excavated straight upwards. As a consequence, the egg-galleries in standing trees are orientated in the same direction; whereas in cut timber this is not the case, longitudinal galleries turning either to the left or to the right from the entrance gallery, which always points downwards.

9. Similar modifications in the direction of the entrance tunnel are found even in species belonging to group 1, which are able to transport the wood-dust upwards. In galleries consisting of two or three longitudinal egg-galleries one notices that in standing trees the mouth of the upper gallery is always to the right or to the left of the lower one, but straight above the funnel-shaped part of the nuptial chamber, which empties into the entrance gallery, this latter acting as an outlet for the shavings. In this way the danger of the shavings falling from the upper gallery into the lower one is obviated. The lower gallery or galleries always start in a curve about half-way up on the sides of the nuptial chamber, the funnel-shaped part of which is therefore below their mouths.

10. These modifications of the shape of the nuptial chamber show that it does not only serve as a nuptial chamber, but also as a receptacle for the detritus until it is finally transported outside the bark.

11. This additional function of the nuptial chamber is also evident from the fact that in many species it is much larger than would be necessary if it served only as a nuptial chamber, as, for instance, in *Carphoborus* (fig. 6, g).

12. Some species, such as *Cryphalus abietis* and *Pityogenes micrographus*, never breed in felled trees. Experiments show that this is not due to the nearness to the ground and the possibly resulting unsuitability of temperature, but only to the fact that these species, owing to their structure and the shape of the chamber, are unable to clean the nuptial chamber or egg-chamber (*C. abietis*) unless aided by the force of gravity, which they can only obtain in standing trees.

13. The direction of the larval tunnels is correlated with the depth to which they are excavated in the surface of the wood. Deep tunnels are as a rule longitudinal, and superficial tunnels are transverse or oblique, or, when they run exclusively in the bark, may follow any direction.

14. The direction of the larval tunnels depend, however, at least at first, on the direction of the egg-galleries. It remains therefore to investigate not only what factors determine this, but also to consider to what circumstances the development of the peculiar, not to say unique, gallery-system of the bark-beetles owes its origin.

15. The necessity of utilising to the utmost the food available in a limited area, which is inherent in the mode of living under bark, and the necessity of obviating the danger to the larvae of their tunnels crossing one another, are, in my opinion, the two fundamental features to which the gallery-system of the bark-beetles owe their origin. In this way the safest maximum degree of density is attained and, at the same time, by the system of egg-galleries with regularly placed egg-pockets the larval tunnels are made to run parallel with one another.

16. When the food of the larva is derived to a great extent from the wood, the larval tunnels are, as a rule, longitudinal, issuing from egg-pockets deeply excavated in the surface of the wood in more or less transverse, deeply engraved egg-galleries.

NEW SPECIES AND HOST RECORDS OF BRACONIDAE.

By D. S. WILKINSON,
Entomologist, Imperial Institute of Entomology.

(PLATE XXI.)

***Urosigalphus*, Ashm.**

Urosigalphus, Ashmead, Proc. U.S. Nat. Mus., xi, 1888, p. 637.

Rhyssosigalphus, Cameron, Trans. Amer. Ent. Soc., xxx, 1904, p. 260 (*syn. nov.*).

None of the species so far described under *Urosigalphus* is known to me, but Cameron's *Rhyssosigalphus* is clearly a synonym of Ashmead's interesting genus.

Szépligeti (Genera Insectorum, fasc. 22', 1904, p. 90) synonymised *Urosigalphus* under *Sigalphus*, Latr. (*i.e.*, *Triaspis*, Hal.); I do not know what authority he had for his action, which was ignored by subsequent writers (Crawford, 1907, 1914; Cushman, 1922).

***Urosigalphus rugosus*, Cam.**

Rhyssosigalphus rugosus, Cameron, Trans. Amer. Ent. Soc., xxx, 1904, p. 260.

This species runs in Crawford's key (Insec. Insc. Mens., ii, 1914, p. 22) to *barberi*, but does not agree with the description of this latter; nor does it agree with the descriptions of species subsequent to and not included in the key.

***Urosigalphus chalcodermi*, sp. n.**

♂. Black; legs (except as follows), tegulae, red testaceous; hind tibiae darkening in apical half, and hind tarsi brown; mandibles reddened basally, the palpi pale; stigma and wing veins brown.

♂. *Head*: face punctate with hardly a trace of rugosity or reticulation, the punctures rather small and well spaced; clypeus differentiated from face by a deep, broad, rounded impression; carinae bordering the antennal grooves strong, the exterior pair continuing down along the margins of the facial orbits for at least two-thirds the height of the face; the inter-ocular prominence very high, in profile thin at apex, much as the scutellar tooth in *Fornicia*; vertex and occiput with broad, smooth reticulation, impunctate; flagellum with 12 joints. *Thorax*: mesonotum with the notauli, and a median area into which they extend and which reaches the posterior margin, broadly and smoothly reticulate; anteriorly to this median area and between the notauli the mesonotum is smooth; there is a well-marked transverse carina anteriorly across in front almost immediately behind the posterior edge of the steep anterior face of the mesonotum, which extends to the notauli on each side, and there is a short, strong, median, longitudinal carina which extends somewhat back into the median anterior smooth area and somewhat down on to the anterior face; anterior face of mesonotum minutely rugose, and the lateral posterior areas smooth save for some minute punctation; mesonotum bounded laterally by a strong crenulate sulcus; mesopleurae almost entirely smooth, bounded above by a large, broadly crenulate area, and anteriorly and posteriorly by a series of foveae; scutellar sulcus broad, deep, crenulate; disc of scutellum slightly, but not prominently, raised, with broad, smooth reticulation; the prominent carina dividing the horizontal anterior area of the propodeon from the perpendicular posterior area not more prominent medianly, but of equal strength throughout, with strong more or less parallel carinae extending from it to the anterior margin of the propodeon. *Legs* short, strong; the hind tibial spurs of equal length, short, about half the length of

the short basal joint of the hind tarsus. *Wings* with the radial complete, the radial cell acute at apex. *Abdomen* with broad, smooth reticulation that tends to form longitudinal lines, particularly anteriorly; laterally the reticulation gradually gives place to round, small punctation; at extreme apex of carapace a very distinct, blunt, median process, below which occurs a pair of sharply pointed spines, which are about as long as the basal joint of the hind tarsus.

Length, 3 mm.

BRAZIL: Bahia, 1 ♂, 1930 (*Dr. G. Bondar*).

Type deposited in the British Museum.

Host. Recorded as a parasite of the Curculionid weevil, *Chalcodermus bondari*, Mshl., damaging cotton twigs.

Although there was only a single specimen available for examination, a description of this species is presented in view of the importance of its host.

Urosigalphus chalcodermi runs in Crawford's key (*Insec. Insc. Mens.*, ii, 1914, p. 22) to *anthonomi*, Crawf., which was bred from the cotton boll-weevil, but differs therefrom in the coloration of the antennae, in the sculpture of the abdomen, which is definitely not describable as "rugose, with coarse punctures," in the sculpture of the median area of the mesonotum and of the scutellum, which is not rightly describable as rugose, and in the colour of the tegulae, these in *anthonomi* being apparently black (no mention being made of them), but in *chalcodermi* being large and very conspicuously shining red-testaceous.

All species described subsequent to Crawford's key are immediately separable by means of, *inter alia*, colour characters.

Phanerotoma hendecasiella, Cameron 1905.

EGYPT: Alexandria, 17 specimens, 8.i.1930 (*M. Kamal*).

Host. Recorded to have been bred from open, green, cotton bolls, and probably parasitic on *Earias*.

This material agrees absolutely both with Cameron's type series from Ceylon, which was bred from buds infested with larvae of the Pyralid moth, *Hendecasis duplifascialis*, Hmps., and with a series from Dehra Dun, India, bred from larvae of a Pyralid, *Nephopteryx rhodobasalis*, Hmps.

Apanteles sundanus, sp. n.

♂. Black; all legs (except as follows), mouth-parts and often to some extent the clypeus, extreme bases of the wings, the excavated basal half of the 1st tergite (which, however, is often darkened), the lateral membranous margins of the 1st and 2nd tergites, the 1st and 2nd ventrites, pale red testaceous or red testaceous; large area of the scape testaceous to red or darkened; tegulae red-brown; hind coxae in basal half above usually black, occasionally only slightly darkened; hind tibiae (except its spurs) and hind tarsi wholly dark brown; stigma and wing veins brown; wings decidedly infumated more or less evenly throughout.

♀. *Head* with only minute and rather sparse punctation; clypeus apparently not differentiated from face, or at least the suture obsolete; facial depressions about equidistant from eyes and apex of clypeus, possibly rather nearer the latter, in the male definitely rather nearer the latter; posterior ocelli about equidistant from each other and the eyes. *Thorax*: mesonotum punctate (degree 3-4), the punctures shallow and rather indefinite, more especially so posteriorly; disc of scutellum with minute indefinite punctation; propodeon smooth, with a strong median longitudinal carina; in addition, the single female has strong transverse basal carinae (at apex of basal fourth of propodeon) running at right-angles from the median carina to the

strong spiracular carinae; the transverse basal and spiracular carinae in the males extremely variable, varying from as strong as in the female, through all stages to entirely wanting. *Wings* (fig. 1): the transverse cubital unusually long; metacarp considerably longer than stigma. *Legs*: hind coxae virtually impunctate, with only some indefinite punctuation basally above, unusually long, about as long as the combined lengths of the three basal tergites, only somewhat shorter than the hind femora; the longer hind tibial spur three-fifths, and the shorter spur two-fifths, the length of the basal joint of the hind tarsus. *Abdomen*: 1st tergite in basal half strongly and evenly excavated, and entirely smooth, in apical half with indefinite minute punctuation (degree 2), from the greatest width of the tergite, which is in the basal sixth, and which is about two-thirds the median length (22:36), the more or less straight sides converge more or less regularly to the truncate apex, which is narrow and only one-ninth the median length; 2nd tergite with discal sulci close together at base, thence extending in a wide sweep to apex, the median length of the tergite rather shorter than that of the 3rd, which latter is half that of the 1st (14:18:36); 2nd and succeeding tergites with only the normal sparse minute punctuation; abdomen in the male shorter than the thorax; ovipositor sheaths of the single female partly concealed, at least half the length of the hind tibiae.

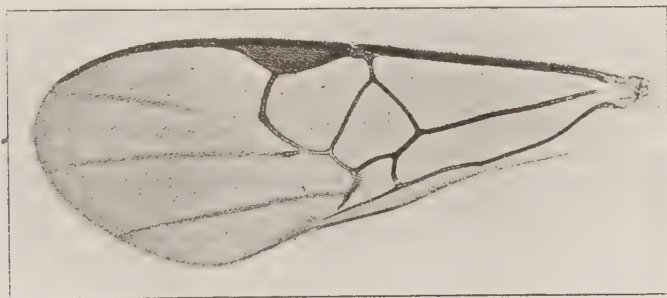


Fig. 1. *Apanteles sundanus*, sp. n., forewing.

Length, 3.0–3.5 mm.

JAVA: Tjibodas, 5,000–7,000 ft., 1 ♀ (*type*), 5 ♂♂, viii.1913 (Dr. Koningsberger).

Type in the British Museum.

Host unknown.

Cocoons unknown.

This handsome species on account of the median longitudinal carina on its propodeon, and its long ovipositor, runs in my key to *eucosmae*, Wilkn., from which it is immediately separable if only on the unusually long hind coxae.

***Apanteles guyanensis*, Cam.**

Apanteles guyanensis, Cameron, Jl. R. Agric. Soc. Demerara, i, 1911, p. 327.

WESTERN AUSTRALIA: Wyndham, 18 ♀♀, 12 ♂♂, iii.1930 (T. G. Cambell).

This species was originally described from British Guiana, and 4 ♀♀ are in the British Museum collections labelled as *type* in Cameron's handwriting.

Host. Cameron's material is without host record; that from Australia was bred from a caterpillar, probably of the Arctiid moth, *Utetheisa pulchella*, L.

Cocoons. The Australian cocoons are white.

The Australian material agrees absolutely with the type series, except that in this latter the abdomen is rather more extensively darkened. In view of the present

host record, and of the wide distribution, I give below a re-description of this species :—

♂. Black ; scape, tegulae, costal veins to some extent, all legs including coxae (except for some slight darkening of the hind tarsi and of the apical fourth of the hind tibiae), and abdomen both dorsally and ventrally (except about apical third to two-thirds, which are darkened), red testaceous ; flagellum brown ; palpi and tibial spurs pale ; stigma and metacarp light brown, the remaining veins more or less colourless.

♀. *Head* : frons and vertex virtually smooth ; face and clypeus with distinct, strong punctation ; clypeus differentiated from face ; facial depressions decidedly nearer to apex of clypeus than to eyes ; posterior ocelli just somewhat nearer to each other than to the eyes. *Thorax* : mesonotum with strong (degree 3–4), separated punctation, smooth along extreme posterior margin ; disc of scutellum with strong punctures, in the greater part smooth ; propodeon not smooth, except possibly medianly, at apex of basal third in the lateral thirds with transverse rugosity looking much like transverse basal carination. *Wings* : the transverse cubital, whose length is about equal to the breadth of the stigma, longer than and roundly angled with the 1st abscissa of the radial, their point of junction often indeterminable ; recurrent rather longer than apical portion of 1st abscissa of cubital, about equal to 1st abscissa of radial ; pigmented portion of 2nd abscissa of cubital short, equal to or shorter than upper portion of basal vein, less than half the transverse cubital ; stigma considerably shorter than metacarp. *Legs* : hind coxae in at least upper half smooth and shining ; the longer hind tibial spur three-fifths, and the shorter spur rather less than half, the length of the basal joint of the hind tarsus. *Abdomen* : 1st tergite smooth and shining save possibly for some indefinite sculpture or punctation towards apex, with median length just not twice basal breadth, in basal half more or less parallel-sided (very slightly converging), in apical third (or even half) strongly and regularly constricted to apex, whose breadth is less than half the basal breadth ; 2nd and succeeding tergites smooth and shining ; the diverging discal sulci of the 2nd tergite fine, straight, reaching the fine, straight 2nd suture, and enclosing an area whose apical margin is three times the length of its basal margin and 1.5 times each of its lateral margins ; hypopygium rather large, acute but not strongly so ; ovipositor sheaths about as long as the basal joint of the hind tarsus.

Length, 2 mm.

Apanteles guyanensis is very close both to *A. lautellus*, Marsh. (testaceous form), and to *A. laxatus*, sp. n. On account of their red testaceous 1st tergites these three species run together in my key, where they have been separated by the following characters :—

Mesonotum without definite punctation, or at most with very shallow, very close, minute punctation giving a semi-iridescent effect ; propodeon smooth ; hind coxae red testaceous ; 1st tergite from about base strongly and regularly constricted to apex (England) *lautellus*, Marsh. (testaceous form)

Mesonotum with minute punctation ; propodeon smooth ; hind coxae darkened to nigrescent ; 1st tergite with sides parallel in at least basal three-fourths, then roundly constricted to apex (Uganda) ... *laxatus*, sp.n.

Mesonotum with definite, strong punctation ; propodeon commonly with transverse basal rugosity that often appears much like transverse basal carinae ; hind coxae red testaceous ; 1st tergite in at least apical third strongly and regularly constricted to apex (British Guiana ; Australia) *guyanensis*, Cam.

Apanteles laxatus, sp. n.

♀♂. Black; scape, mouth-parts, all legs (except coxae), abdomen both dorsally and ventrally (except in apical third which is slightly darkened), red testaceous; hind coxae darkened to nigrescent, except below at apex where they are red testaceous; hind tibial spurs not pale, but coloured as the legs; palpi pale; stigma and wing-veins light brown.

♀♂. *Head* with only minute punctation; clypeus not differentiated from face; facial depressions decidedly nearer to the apex of the clypeus than to the eyes; posterior ocelli nearer to each other than to the eyes. *Thorax*: mesonotum and disc of scutellum with regular, fairly close, minute punctation; propodeon smooth and shining. *Wings*: the 1st abscissa of the radial in length equal to the breadth of the stigma, longer than, and slightly but always definitely angled with, the transverse cubital, twice as long as the apical portion of the 1st abscissa of the cubital, this latter equal to or rather longer than the pigmented portion of the 2nd abscissa of the cubital, equal to or rather shorter than the upper portion of the basal vein, and shorter than the recurrent; stigma shorter than metacarp. *Legs*: hind coxae in at least upper half smooth and shining; the longer hind tibial spur eight-elevenths, and the shorter spur six-elevenths, the length of the basal joint of the hind tarsus. *Abdomen* with the tergites smooth and shining; the 1st tergite with its median length 1.66 times its median breadth, with the sides parallel for rather more than basal three-fourths, then roundly constricted to apex; 2nd tergite with apex arcuately emarginate, its discal sulci straight and smooth and only just reaching the exceedingly fine 2nd suture; hypopygium almost acute; the ovipositor sheaths about as long as the basal joint of the hind tarsus.

Length, 2.0–2.25 mm.

UGANDA: Kampala, 8 ♀♀, 1 ♂, 9.vii.1919 (C. C. Gowdey).

Type deposited in the British Museum.

Host unknown: the parasites are labelled "No. 6747."

Cocoons unknown.

Apanteles laxatus is very close to *A. lautellus*, Marsh., and *A. utetheisae*, sp. n., but may easily be separated by means of the key that I have given after the description of this latter species.

Apanteles australiensis, Ashmead 1900.

AUSTRALIA: Victoria, 14 ♀♀, 7 ♂♂, iii.1929 (A. M. Wade, through L. F. Graham).

Host. The larva of a Saturniid moth, *Antheraea eucalypti*, Scott.

Cocoons. A photograph of the cocoon-mass is given, for which I am indebted to Miss Graham (Plate XXI); alongside the mass is an unparasitised larva. This mass is much like that of *A. acherontiae*, Cam. (Green, Spol. Zeyl., v, 1907, p. 19; McCann, J. Bombay N.H. Soc., xxxi, p. 727), of which there is a specimen in the British Museum collections. Mr. Wade writes that there were 938 cocoons.

Fornicia thoseae, sp. n.

♀. Black; mandibles (except at base), and the greater part of the scape, red; some basal flagellar joints slightly reddened; apical two-thirds of the front femora, front tibiae and their spurs, front and middle tarsi, pale red testaceous; middle tibiae blackish beneath in the middle, white at extreme base, with their spurs white, otherwise pale red testaceous; hind tibiae in basal third white, slightly reddened at extreme apex internally, otherwise black with their spurs white; wing veins at extreme base of wing pale, otherwise dark brown, the costal veins otherwise and the stigma and metacarp dark brown to black; fore-wings distinctly infumated in apical

third, that is to say beyond a line drawn from about apex of stigma through the transverse cubital to the apex of the anal vein; hind-wings faintly infumated in apical third and round the discoidal margin.

♀. *Head*: face with minute punctation, the clypeus smooth in a large median basal area; vertex and occiput smooth with only minute and sparse punctures; flagellum longer than combined length of head, thorax, and abdomen. *Thorax*: mesonotum with median third in anterior two-thirds very definitely excavate, with a very well marked median longitudinal carina, which extends into the posterior third; median posterior third rugoso-reticulate, as are the notauli, which, extending from this area but discernible only up to about the middle of the mesonotum, materially assist in accentuating the anterior excavation, being smoothly raised; lateral areas of mesonotum otherwise strongly, evenly grossly, punctate, except, on each side near the tegulae, for a narrow longitudinal strip, which is rather more weakly punctate (although still fairly strongly so), much as the punctation of the median anterior excavate area; disc of scutellum in basal half closely reticulate, in apical half with the reticulation very decidedly larger; scutellar process bidentate; metanotum medianly with a prominent spine-like process; propodeon with the major carination much as in *F. ceylonica*, Wilkn., strongly carinate beyond the costulae. *Legs*: hind coxae on outer faces with close, fairly strong punctures, not reticulate nor rugoso-punctate, except towards apex; the longer hind tibial spur four-sevenths, and the shorter spur three-sevenths, the length of the basal joint of the hind tarsus; hind tibiae and tarsi strongly setiferous, the setae strong and close. *Abdomen*: very like that of *F. ceylonica* except that the raised median longitudinal area is narrower and not so well defined, in fact in the 3rd tergite occurring only as a rugose carina (and that only in basal third), while in addition the longitudinal carinae are weaker with the interspaced transverse carinae stronger and considerably less regular, the interspaces in fact more rightly describable as weakly reticulately rugose; only the lateral longitudinal carinae reach the apex of the 3rd tergite, the others pairing and not reaching the apex, thus differing from those in *ceylonica* and *africana*.

Length, 6.5 mm.

CELEBES: Manado, 1 ♀, 10.v.1930 (*A. Reyne*).

Type deposited in the British Museum.

Host. Larva of a Limacodid moth, *Thosea portheles*, Tams, sp. n. (see p. 490), damaging coconut palms.

This species runs in Cushman's key (*Phil. J. Sci.*, xl, 1929, p. 234) to *tagalog*, but does not agree with the published description of this latter. It is easily separable from *ceylonica* and *africana* on the colour of the hind femora, and on the nature of the sculpture of the tergites.

Cardiochiles adina, sp. n.

♂♂. Black; palpi, and the anterior tibiae and tarsi, with their spurs, pale red testaceous; hind tibial spurs brownish; the 1st tergite (save for a very small, median, somewhat elongate, tuberculate area in apical third) together with both its own lateral membranous margins and those of the 2nd tergite, very pale to white, the basal sternites very pale; fore-wings hyaline in about basal half, strongly and evenly infuscated in apical half (fig. 2), with veins dark brown to black; hind-wings definitely infuscated in apical fourth.

♀♂. *Head* smooth save for minute and somewhat sparse punctation; face short and strongly transverse, its median length only half its breadth and only 1.66 times the median length of the clypeus; clypeus differentiated from face by a strong but smooth suture; facial depressions deep, decidedly nearer to apex of clypeus than to the eyes, their distance from each other virtually twice the length of the clypeus,

this latter length being equal to the malar space and slightly greater than the distance from the eyes to the facial depressions; ocelli virtually in an equilateral triangle, their distance from each other about the breadth of an ocellus, the posterior pair with their distance from the eyes about three times the breadth of an ocellus. *Thorax*: mesonotum with only minute punctation; the notauli broad and deep, crenulate; scutellar sulcus very large and deep, strongly crenulate; disc of scutellum medianly smooth, at sides and apex crenulate and strongly margined; mesopleural sulcus strong and strongly crenulate. *Legs*: hind coxae with only minute, sparse punctation; the longer hind tibial spur three-fourths, and the shorter spur one-half, the length of the basal joint of the hind tarsus.

Length, 3.5-4.0 mm.



Fig. 2. *Cardiochiles adina*, sp. n., fore-wing.

INDIA: New Forest, Dehra Dun, U.P., 4 ♀♀, 1 ♂, 4.x.1929 (*type*), 27.ix.1929 (*N. C. Chatterjee*), 18.ix.1929, 23.ix.29 (*R. N. Mathur*).

Type deposited in the British Museum.

Host. Recorded as parasitic on a larva defoliating *Adina cordifolia*.

In Brues' key to his own species (*Ann. S. Afr. Mus.*, xix, 1924, p. 92), *Cardiochiles adina* runs to the last couplet, but is immediately separable from the two species therein contained. It will not run in Turner's key to the Australian species (*Ann. Mag. Nat. Hist.* (9) i, 1918, p. 49), but in Enderlein's key to the Indo-Australian and Ethiopian species (*Stett. Ent. Zeit.*, lxvii, 1906, p. 245) it runs to *fasciatus*, Szép., which, however, has the base, and only the apical third, of the wing darkened.



Cocoon-mass of *Apanteles australiensis*, and an unparasitised larva of its host, *Antheraea eucalypti*.

FOUR MOTHS OF THE FAMILY LIMACODIDAE INJURIOUS TO COCONUT PALMS.

By W. H. T. TAMS.

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(PLATE XXII.)

Of the four moths dealt with in this paper, three are known to damage coconut palms in Celebes, and the fourth behaves similarly in the Gold Coast. Three of the species are here described as new. The opportunity has been taken to figure the larvae as well as the imagines of the Celebes species, and to include figures of *Orthocraspeda catenatus*, Snellen, of which two larvae and a pair of imagines were received with the other Celebes material. The short descriptions of the larvae are taken, with slight modifications, from Mr. A. Reyne's letter which accompanied the specimens. All the material concerned has been generously presented to the British Museum (Natural History) by the Director of the Imperial Institute of Entomology.

Orthocraspeda catenatus, Snellen (Plate XXII, figs. 1, 2, 10).

Limacodes catenatus, Snell., Tijdschr. v. Ent., xxii, p. 121, pl. x, fig. 3 (1879).

These are the first specimens of this species to reach the British Museum. The larva is dark brown with peculiar white spots dorsally, green ventrally, the dorsal and ventral coloration separated by white. The full-grown larva is 14 mm. in length, and noticeably higher at the head than at the tail. It has two parasites, a Hymenopteron, *Chrysis* sp. (not yet determined), and a Dipteron, *Chactexorista* sp., near *C. javana*, B. & B.

This Limacodid has so far only been observed at the coconut estate Lolak, on the north coast of Celebes some 200 km. west of Manado (Menado). Mr. Reyne states that not only is the damage by the caterpillar extensive, in spite of a mortality of some 80 per cent. (? from a bacterial disease), but that it is still further increased by the fungus *Pestalozzia palmarum* (grey blight), which attacks the leaves at the places where they are damaged by the caterpillars.

Material: ♂, ♀ and 2 larvae, labelled: Lolak, 10.v.1930. Cocoon chestnut-brown, nearly spherical, 7.5 mm. in diameter.

Altha alastor, sp. n. (Plate XXII, figs. 5-9).

♂. Palpus light buff to warm buff, shaded on outer side with fuscous black. Antennae honey-yellow. Head cartridge-buff to light buff, slightly tinged with argus-brown between the antennae. Thorax light buff mixed with argus-brown, tegulae proximally cartridge-buff. Tergum light buff to warm buff, crests tipped with argus-brown. Pectus light buff, finely streaked with fuscous black in front. Legs cartridge-buff to warm buff, irregularly shaded with argus-brown, the fore femur irrorated with fuscous black, the mid tibia and mid and hind tarsi with some of the long scales tipped with fuscous black. Venter light buff, cartridge-buff terminally. Fore wing cartridge-buff, the proximal two-thirds suffused with argus-brown, this colour varying in intensity and particularly pronounced at end of cell and in a spot below middle of cell; irregularly distributed patches of fuscous black irroration, with a definite dot at lower angle of cell and a well-defined spot at tornus; an oblique zig-zag antemedial fascia from middle of costa to just before middle of inner margin, cartridge-buff; edge of proximal argus-brown area oblique from costa at two-thirds to vein M2 at two-thirds, then bowed (convexity terminad) to tornal spot

close to termen, then rounding tornal spot to inner margin at two-thirds; a pre-terminal fascia of argus-brown shading, widest at vein R5, narrowing to tornus; traces of fuscous black edging on termen interneurally between veins R3 and M1, and at ends of veins Cu1 and Cu2; fringe light buff; hind wing light buff, the long hair-scales on inner marginal area tinged with avellaneous. Underside light to warm buff, fore wing with sparse fuscous irroration on base of costa and radial veins. Expanse: 25 mm.

♀. Much larger, similar, but with certain striking differences. Fore wing cartridge-buff, the argus-brown suffusion and markings almost restricted to the distal two-thirds of the costal half of the wing, with faint traces in the inner marginal half antemedially, postmedially and before the termen; a fuscous black dot at lower angle of cell, but no fuscous black spot at tornus. Underside similar to that of ♂, but with more fuscous shading apically. Expanse: 36 mm.

Holotype ♂ and allotype ♀: N. Celebes, Poigar, 12.iii.1930, larvae on coconut palms (*A. Reyne*).

The larva (figs. 7-9) is a white jelly-like caterpillar without setae, with a peculiar chlorophyl-green longitudinal mark dorsally. It does little damage. The cocoon has a silvery grey appearance, is nearly spherical and 9 mm. in diameter.

***Thosea porthetes*, sp. n. (Plate XXII, figs. 3 & 11).**

♂. Palpus blackish brown, the scales finely tipped with drab grey producing the appearance of fine indistinct irroration. Antenna with shaft blackish brown, pectinations honey-yellow, the inner row clothed with blackish brown scales. Head and thorax blackish brown, the scales finely tipped with drab grey. Abdomen (tergum) clove-brown. Pectus and legs blackish brown, scales finely tipped with drab grey. Venter clove-brown. Fore wing seal-brown, with an obscure fuscous black spot on discocellulars, and an obscure fuscous black postmedial fascia parallel with termen. Hind wing clove-brown, fringe clove-brown broadly edged with pale drab grey except at anal angle, where it is edged with fuscous. Underside seal-brown; fore wing with costa at apex broadly edged with drab grey. Expanse: 21 mm.

Holotype ♂: N. Celebes (*A. Reyne*). Larva on coconut palm.

The larva is green, with a blue medial line dorsally. It does little damage, and is always heavily parasitised by a Braconid, *Fornicia thoseae*, Wilkinson.

***Thosea chrysoparala*, sp. n. (Plate XXII, fig. 4).**

♀. Palpus chestnut-brown, ochraceous orange above, below and on inner side. Antenna cinnamon to Mikado brown. Head cinnamon in front, vertex Mikado brown, irrorated with vinaceous buff. Thorax and tergum cinnamon to Mikado brown, irrorated with vinaceous buff. Pectus cinnamon, ochraceous orange mixed with chestnut-brown in front. Venter Mikado brown irrorated with vinaceous buff. Legs chestnut-brown, streaked and banded with ochraceous orange. Fore wing Mikado brown with scattered bone-brown irroration; a diffuse bowed (convexity tornad) bone-brown fascia from costa at three-fourths to inner margin at one-third; a diffuse bone-brown bowed (concavity terminad) fascia from apex to tornus, the succeeding area and fringe tinged with Saccardo's umber. Hind wing Mikado brown, fringe Saccardo's umber. Underside fore wing avellaneous to Mikado brown, with some cinnamon towards costa and on veins; hind wing avellaneous to Mikado brown, sparsely irrorated with prominent bone-brown scales. Expanse: 30 mm.

Holotype ♀: Gold Coast, Western Province, Atwabo, xi.1927 (*G. S. Cotterell*).

The larva damages coconut foliage.

EXPLANATION OF PLATE XXII.

- Fig. 1. *Orthocraspeda catenatus*, Snellen, ♂.
 „ 2. „ „ „ „ ♀.
 „ 3. *Thosea porthetes*, sp. n., ♂.
 „ 4. „ *chrysoparala*, sp. n., ♀.
 „ 5. *Altha alastor*, sp. n., ♂.
 „ 6. „ „ „ „ ♀.
 „ 7. „ „ larva, ventral view (×2).
 „ 8. „ „ „ lateral view (×2).
 „ 9. „ „ „ diagram of dorsal pattern.
 „ 10. *Orthocraspeda catenatus*, Snellen, larva (×2).
 „ 11. *Thosea porthetes*, sp. n., larva (×2).



1.



2.



3.



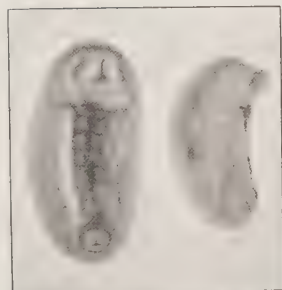
4.



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6.

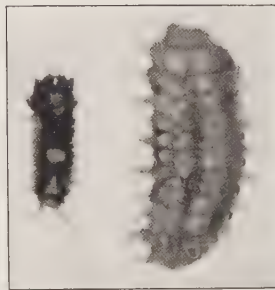


7.

8.



9.



10.

11.

Limacodidae injurious to coconut palms.

CONTRIBUTIONS TO THE BIONOMICS OF *GLOSSINA MORSITANS*.

By C. H. N. JACKSON, PH.D., M.Sc., F.E.S.,
Zoologist, Department of Tsetse Research, Tanganyika Territory.

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PREFACE.

While the concept and detailed results set forth in this paper are largely due to the writer, many suggestions and data have been kindly furnished by other members of the Department.

In particular it is desired to acknowledge the large proportion of his time devoted by Mr. W. H. Potts, Senior Entomologist, to considering suggestions and to discussing the feeding-ground concept during all the stages of its development. His valued criticisms have set right many inaccurate and unconsidered statements. He also spent much time in the field co-operating in the investigation of the phenomena associated with the "catching-out" experiments, and the grading of flies according to hunger was determined with his help.

Thanks are due to Mr. Burt, Botanist, Sambala, for placing at the writer's disposal his physical and biotic data from the ecological stations. Mr. Burt co-operated in the recapture and careful recording of marked flies taken on his ecological rounds, and data obtained from flies marked by him have also been used in this paper. In addition, Mr. Burt gave much patient help in the naming of trees and in describing their characteristics in such a way as to make identification easier at any time of year.

Constant encouragement and helpful criticism were given by the Director on his visits, and particularly it is wished to acknowledge his very relevant suggestions

at various stages of the field experiments, suggestions which led to a consideration of numerous weak points and to the taking of measures for their elimination.

Finally, the writer has to thank Dr. J. F. V. Phillips, Deputy Director, for his sympathetic criticism, advice, and encouragement throughout the progress of the work, and for his very detailed examination and criticism of the present paper.

Kikori, 9th November 1929.

I. Introduction.

The Zoologist has worked as a member of the Department of Tsetse Research since September 1927. Before proceeding to the Sambala Research Station, Western Kondoia Irangi, in April 1928, he spent about three months at Shinyanga (*Glossina swynnertoni* and a few *G. pallidipes*), and a similar time was occupied in investigating the Eastern Fly Belt at Kondoia Irangi (*G. morsitans* and *G. swynnertoni*).

It has thus been possible to gain some acquaintance with a relatively wide range of faunal, floral, and physiographical conditions and to preserve the wide outlook essential to the interpretation of data since collected in a relatively prescribed area over a considerable time.

The aim has been to obtain in the first place a series of long-continued, comprehensive, critical observations in carefully chosen representative areas. Note has been kept of the nature and numbers of the flies coming to man, the numbers and movements of the species of game animals present, and the general nature and seasonal aspects of the local vegetation.

These observations suggest interpretations which are susceptible of being tested by a logical series of field experiments, helped occasionally by laboratory work, and, when possible, correlated with data relating to physical conditions of the habitat.

The investigation therefore falls under two heads :—

- (i) Observations supplying facts from which indirect evidence is obtained.
- (ii) Experiments to interpret these observations through evidence of a more direct nature.

II. Difficulties in the Interpretation of Fly Numbers.

There are two methods of collecting flies on man : Standing in one spot and collecting all the flies that come ; or proceeding steadily along a given transect and collecting flies that attack along the route. These methods share a common limitation in that the flies collected represent :—Flies present from the start and attacking at once, flies present from the start but not at once attacking, and flies arriving during the progress of the catching.

The longer the catch continues, the higher will be the proportions of reluctant and arriving flies. Shortening the time of catching decreases the importance of reluctant and arriving flies ; but if the time be too short, the catchers may be unable to deal with the flies present and eager to attack, and the figure obtained will fail to indicate the apparent density.

(In the disposal of present and eager flies, the time taken is not of significance, since if the catchers were sufficiently skilful *all* these flies would be taken at the start ; on the other hand the time is important in dealing with reluctant and arriving flies, the skill of the catchers being ordinarily sufficient to cope with these as they come.)

The foregoing difficulties are common to catches made along transects and to catches made standing in one place. Transects have certain sources of error peculiar to themselves :—

(i) The speed of the catchers, whatever speed is decided upon, may affect differently the numbers and character of flies attracted in different transects. (By character are meant the proportion of sexes and of young flies to old, and the physiological condition of the flies.)

(ii) In a short transect flies drawn in from ahead and behind may seriously swell the numbers properly belonging to that transect, and at the same time remove an appreciable number of flies from the transect ahead as the catchers slowly approach.

However, provided that the number of catchers is constant, and every transect or standing catch occupies the same length of time and is carried out at the same time of day, it is considered that the fly numbers obtained are sufficiently accurate to have some scientific value, whatever their real meaning may be.

Flies collected in the field can bear only a limited relation to the flies in the area of bush from which they have come. They are not necessarily a true index of the fly population of that bush. The proportion of flies which will consent to attack man is bound to vary with type of country, time of day and year, the time which has elapsed since their last meal, and a number of less obvious factors.

The condition of those flies which show themselves is, moreover, unlikely to indicate directly the condition of their companions which do not appear.

In order to arrive at a truer estimate of the meaning of data collected by a single method, it is necessary to apply a number of methods in combination to specific problems of fly behaviour. Afterwards it may be possible to devise simple tests for the diagnosis of any given fly situation, and perhaps to interpret past observations obtained by any one method alone.

To take an example of the difficulties attending the interpretation of data, one may consider the meaning of apparently young flies taken in the catches.

These are recognisable by the softness of their chitin and by the fact that the ptilinum is usually capable of being expressed by forceps. Experiments performed by Mr. Potts seem to show that the flies remain in this condition until after their first meal, before which they may live up to six days. It is therefore evident that if, owing perhaps to scarcity of food, or to cold or other factors inhibiting activity but not emergence of fly, the average wait before the first meal is increased, the proportion of young flies may appear to increase irrespective of any increased rate of emergence in nature. On the other hand, old flies have all fed at least once, and perhaps are generally less hungry than freshly emerged flies. Under starvation conditions the old flies might show themselves in something like their true proportions, while the number of young flies would be less strongly increased; the proportion of apparently young flies would therefore fall. Or, finally, an increased death-rate of old flies in nature would heighten the proportion of young flies.

While such considerations may have small practical bearing on the meaning of the data collected, they are mentioned to show that they have not been altogether overlooked, and that the path of the tsetse investigator is beset with difficulties which may not at first be very apparent.

III. Methods of Investigation.

A. Reconnaissance.

The object is to secure data on game and fly, vegetation and topography, over a large area surrounding the country chosen for observation; to supplement the investigation of the narrow strips of country included in the selected transects or "fly-rounds"; and to gain a comprehensive conception of the fly belt as a whole.

The methods adopted are as follows: Note is made of the general nature of the country traversed, and of animals and "spoor." Flies are caught, killed, and retained for examination at the end of the day. The route is divided into appropriate transects according to environmental factors, including vegetation and water-holes and other places favoured by game. Attention is paid to boundaries, stable and unstable, of the fly belt, and the reasons for fly distribution are considered. Native information may sometimes be of use.

B. *Fly-rounds.*

The object is to secure regular, continuous, and so far as possible comparable data on the occurrence, movements, and bionomics of game and fly in a representative series of vegetation types.

Fly-rounds was the name given in 1927 by Mr. W. H. Potts to subdivided transects selected by him for regular observation. The original method is employed with only minor modifications at Sambala.

Blazed trees indicate a path traversing a representative series of vegetation types and situations more or less attractive to game. The path is divided into a series of beats or transects by numbered trees at suitable intervals, marking off vegetation communities, water-holes, paths, stamping grounds, and any other features of importance. Where the route passes from a thin-fly beat to one with thicker fly, the dividing tree is chosen a few yards inside the thin-fly section, to minimise the error due to flies attracted out of the alternate beat.

The rounds, according to their estimated importance, are carried out once or twice in about every ten days; when rounds are done on two days in ten these days are consecutive. The round starts at 9.0 a.m. and is passed through at a roughly constant speed by a party of three. One individual walks ahead, noting accurately the game "spoor" in the separate transects, with estimates as to the probable time of passage of the animals, and the general weather conditions. He is followed by the other persons who catch and kill all, or as many as possible of the flies coming as the party proceeds, and place them in glass tubes. On arrival at the numbered trees, the man in front receives the flies caught in the transect, transfers them as quickly as possible to his own tube, and shuts them off from the previous batch with a paper plug; the party then proceeds as before.

Rather more than half of the rounds are supervised by a European. The work of natives is checked by doing the round on the second of every pair of catching days, and noting the correspondence in the records of spoor.

Flies received from the rounds are counted, sexed, and examined for young (soft) flies and pregnant females, the game data being entered on the same form.

A fly is considered *young* provided that it is *soft* and will exert its ptilinum when the sides of the head are pressed with forceps. A female is considered fully pregnant when the black lobes of the larva can be discerned without dissection.

Unfortunately, note has not until recently been kept of the general external condition of flies collected. Lately a rough system of grading according to probable hunger has been evolved. While it is realised that appearances may often be deceptive, it is felt that the system has some general meaning and is worth examination and further development.

The grades used (determined with the help of Mr. Potts) are as follows:—

Grade I. Abdomen distended with red or black blood visible from outside.

Grade II. Abdomen distended in both directions, but without black blood visible from outside.

Grade III. Abdomen not distended or wrinkled, usually white in appearance and not concave below.

Grade IV. Abdomen beginning to wrinkle, sometimes distended by a gas bubble at the front end. Frequently straw-coloured on the ventral side.

Grade V. Abdomen definitely concave or flattened, sometimes waferlike.

Grade VI. Young (soft) flies.

Grades I, II, and III are usually considered as the repleter ones, grades IV, V, and VI as the hungrier. Grade II is generally rare, which may indicate that this stage is a short-lived one.

C. Collecting on Cattle.

This takes the same general form as fly-rounds, except that cattle are used as bait in addition to man.

D. Field Experiments.

As a great deal of time has been spent on field experiments in search of satisfactory methods not open to important objections, it may be worth while to touch on some causes of the rather meagre results achieved, and to indicate lines which it is hoped will be followed in the future.

1. Marking of flies. Oil paints are infinitely superior to coloured "blanco" mixtures. Individual flies can be identified conveniently by a system of clock-marking with various two-colour combinations, one colour representing the hour and the other the minute-hand, and both being made to occupy various positions around the periphery of the thorax. This leaves the disc of the thorax free. At the time of writing the marking seems to be permanent. Only a minimum of medium is necessary to mix with the paints, which may best be applied on the end of a grass-stem.

2. Attempts were made to use some receptacle for conveying from place to place flies the condition and place of origin of which were known, and releasing them in absence of man. A wooden box covered with muslin was employed, the muslin being removed from a distance by a long string passed over the arm of a tree. Unfortunately, while this method was satisfactory for repleter flies (50 or 100 at a time), it appeared that hungry flies were relatively unwilling to leave the neighbourhood, in whatever type of country, when the box was opened. After a fairly long trial these experiments were therefore abandoned as giving suspect results.

3. Following on these failures, a differential system of marking was evolved, which made it possible to tell on recapture the date, vegetation type, and approximate hunger-condition of the fly at the time of the first marking. At the same time the recaptured flies were given individually distinctive markings on the clock system described above. Flies could thus be marked and released without confinement of any sort, but nevertheless under conditions fairly accurately known.

IV. The Nature of the Country.

Sambala is situated, at an elevation of 4,700 ft., about 27 miles W.N.W. of Kondoa Irangi, among undulating hills. The Sambala sand river rises 12 miles north of the Station, and a little below Sambala loses itself in a broad "mbuga" or seasonal swamp. From about 6 miles to the south the country rises into a low plateau with shallow, tenuous valleys running down south-westward to the Mekenke River in the Sandawe country. North and east of the Station the country is hilly, rising slowly to the edge of the open Mangati Plains. To the west the hills slope down into an extensive thicket.

The following remarks on the climate are based on observations resulting from a residence of a year and a half in Sambala only, and are therefore subject to reservations.

There were recognisable the following seasons, which are said to vary slightly from year to year :—

1. *Early Dry Season* (May to July).

A cold period following the rains. Water is generally plentiful, and leaf-fall in progress. The sky is often overcast until the afternoon. Light rain showers may still fall.

2. *Mid Dry Season* (August to October).

The temperature rises, and the non-permanent water-holes dry up. The sky is seldom clouded. Small whirlwinds are common. When the grass fires occur young vegetable growth appears locally in moist spots.

3. *Late Dry Season* (October to December).

About October the first rain falls. Pools appear among rocks and may last for several days. A carpet of young grass covers the burnt ground over the hills, but the majority of the trees develop no leaf. This young grass later shrivels until more rain falls. Some of the semi-permanent water-holes may now dry, and others are kept open by the tunnelling of wart-hogs or the digging of elephants, only.

4. *The Short Rains* (December to January).

The rains break rather suddenly, and the trees immediately burst into leaf. The grass revives and begins a rapid growth. There are violent thunderstorms, usually in the afternoon.

5. *The Short Dry Season* (February).

This lasts about a month. Rain is infrequent or absent and the weather very hot with low relative humidity. Much of the grass shrivels, as do the leaves on some of the thicket shrubs.

6. *The Long Rains* (March to April).

Thunderstorms are less frequent. During the first half of the period the storms are heavy, and usually occur in the afternoon; later the rainfall is slighter and scattered showers fall throughout the day. The grass attains its maximum height, and the leaves of some trees begin to assume "autumn" tints.

The wind is easterly to south-easterly during the whole of the year, generally less strong during the rains. There is no frost.

V. The Vegetation of the Area.

Broadly, the area is divisible into wooding, open country, and thicket, of which only the first seems really suitable to the fly. A more detailed examination distinguishes the following categories of vegetation communities :—

1. *Berlinia-Brachystegia* Wooding.

This wooding covers more or less a third of the country and is known to the natives as "miombo." It is generally found covering the low undulating hills up to 5,500 ft. The dominant trees are *Berlinia globiflora*, *Brachystegia itoliensis*, and *B. edulis*. *Brachystegia microphylla* is found on ridges and rocky outcrops generally. Other common trees in these communities are *Terminalia sericea* and *T. hildebrandii*, *Ostrya derris stuhlmanni*, *Pterocarpus bussei*, *Combretum zeyheri*, *C. splendens*, *C. apiculatum*, and scattered *Sclerocarya*, especially in the moister parts. In the outskirts the species of *Combretum* are more numerous, together with *Commiphora fischeri*, *C. schimperi*, *C. subsessilifolia*, *C. boehmii*, and *C. ugogensis*, *Strychnos heterodoxa*, and *Hymenodictyon*. The grass growth is, in the Sambala area, usually rather poor; the fires are fairly complete. Leaf-fall begins about a month or two

months after the start of the dry season, and reaches its maximum about September, when trees sporadically come into leaf. The general flushing does not, however, occur until the arrival of the short rains.

Except in the Samba area south of the Kondoa-Singida road, *G. morsitans* appears generally spread through this type of wooding. Where the stands are relatively pure, there usually is a low percentage of females and young flies attracted to man, although puparia commonly are found in most of the likely sites. Females and young flies chiefly are met in the outskirts, and especially in narrow glades with subsoil moisture or pools, where there is not much overhead shade.

2. *Acacia stenocarpa*-*A. senegal* Country.

These small trees, with *A. hebecladoides*, *Dalbergia melanoxylon*, *Commiphora* spp., and occasional *Acacia spirocarpa*, form open woodland on stony hilltops and low weald-like elevations between streams, where the soil covering is thin. There is a good growth of grass, which burns well. Owing to the open character of the wooding there is never any considerable overhead canopy, and visibility is generally very much better than in the *Berlinia-Brachystegia*.

G. morsitans is fairly common in this type, and, as in the *Berlinia-Brachystegia*, the proportion of young and female flies is ordinarily low.

3. *Acacia roovumae* Country.

A. roovumae is a tall, massive tree dominating country with heavy soils, somewhat swampy during the rains, but without surface moisture at other times. It usually occurs with *Acacia drepanolobium*, *A. mellifera*, and in many places with *A. kirkii*, a species discussed more fully below. Other common species are baobabs (*Adansonia digitata*), *Lannea humilis*, *Commiphora* spp., the shrub-like *Ormocarpum trichocarpum*, and numerous Capparids. The low-growing, soft-stemmed *Coleus igniarius* is an important feature. Grass is very scanty, its place being taken by a perennial Acanthaceous stratum of what is known locally as "asbestos weed," *Barleria* spp., which is very resistant to fire. There is frequently a certain amount of thicket.

Fly inhabiting *Acacia roovumae* bush exhibits every degree of apparent density, and great variation in condition and sex.

The glades and drainage valleys of *Berlinia-Brachystegia* wooding frequently open out into *Acacia roovumae* bush.

4. *Acacia kirkii*.

As noted above, this large shrub is often an important constituent of *A. roovumae* country, where it may be the dominant tree. It also may occur fairly pure over large areas; in moister places *A. kirkii* may be replaced by *A. stuhlmanni*, a species of similar habit. The country is very swampy in the rains. *Acacia kirkii* is not found in the north of the area where there is better conservation of water.

Fly may be either common or exceedingly scarce in *Acacia kirkii*, and it is suggested that this depends on the size of the area, larger tracts being perhaps unfavourable.

5. *Acacia spirocarpa*.

This large flat-topped tree is found in river valleys and other situations with subsoil moisture. Where rivers spread into seasonal swamps ("mbugas"), or in glades among *Berlinia-Brachystegia*, it may occur with *Acacia verrugera*, *A. albida*, *Kigelia*, and *Lonchocarpus capassa*. The grass may be long, and blue *Vernonias* are a common feature. Fires are frequently very incomplete.

Fly is often common where the country is not too open.

6. Thicket.

According to Mr. Burt, the thickets of this area differ from those of the Itigi-Kazikazi regions of the Central Province in the possession of numerous tree *Commiphora*, which not only break up the thicket to some extent, but provide the reason for a network of elephant and rhinoceros paths within it. Apart from these trees, the chief constituents of the thickets are *Combretum trothae*, *Grewia platyclada*, *G. holstii*, *Vangueria*, *Acacia pennata*, and the small shrubs *Abrus schimperi* and *Justicia salviflora*. Almost the only grass is a species of *Setaria*. The thickets are fairly impenetrable by fire. Drainage valleys running through thickets usually contain *Acacia rooseumae* and its associated flora. Like *Berlinia-Brachystegia*, thicket is very extensive in the Sambala area, and covers about a third of the country south of the Mangati Plains.

Where thickets are extensive fly is uniformly very scarce ; but thicket elements occur scattered through almost every kind of bush, both in valleys and over hills.

7. Open Country.

Most of the mainly open country exhibits a richer or poorer grass growth on black alluvial soil, with no permanent sources of water. Trees, where they occur, include chiefly *Acacia formicarum*, and, on the Mangati Plains, *Acacia seyal*.

In open country away from bush, fly is scarce or absent.

The herbaceous *Courbonia edulis* in some localities provides grazing in open country after the grass fires, and is eaten by zebra and probably other game. Small villages occur in the south and east, but the cultivated area is inconsiderable.

Fly is generally, but not always, scarcer in cultivation than in the country immediately surrounding, and the percentage of females and young flies rather high.

VI. The Game Animals of the Area.

The area includes the following species of game animals :—

A. Carnivorous Species.

Lion	...	...	...	Scarce generally ; common on Mangati Plains.
Leopard	...	...	...	A few individuals.
Cheetah	...	...	...	Rare.
Hyaena, both species	...	...	...	A few individuals ; abound on Mangati Plains.
Hunting-dog	...	...	...	Casual.
Aard-wolf	...	...	...	Alleged to occur.
Jackal	...	...	...	A few ; common on Mangati Plains.

B. Herbivorous Species.

1. Game of fixed habits, individuals having, relative to their size, a restricted range.

Giraffe	...	...	...	Common.
Greater kudu	...	...	...	A few pairs and parties.
Lesser kudu	...	...	...	Fairly common south of Sambala.
Rhinoceros	...	...	...	Common.
Bushbuck	...	...	...	Common.
Reedbuck (Bohor)	...	...	...	A few individuals and parties.
Duiker	...	...	...	Common.
Steinbuck	...	...	...	Fairly common.
Klipspringer	...	...	...	Most rocky hills.
Dikdik	...	...	...	Common.
Pygmy antelope or suni	...	...	...	Fairly common locally.

(Many of these smaller species show a seasonal shifting of a mile or so from long-grassed to thicketed areas. The steinbuck and klipspringer are not affected in this way.)

2. Game more or less stationary when water is plentiful but capable of large daily movement when it is scarce.

Waterbuck	Very rare.
Impala	Mangati Plains or near; occasionally elsewhere.
Thomson's and Grant's gazelles.	Mangati Plains; fairly common.
Wildebceest	Common on Mangati Plains.

3. Migratory species.

Eland	Common in Sandawe country and Mangati.
Roan	Fairly common and widespread.
Zebra	Common.
Kongoni (Coke's hartebeest)	Common; not found in Sandawe country except the north edge.
Buffalo	Fairly common.
Ostrich	Common.
Elephant	Perhaps 50 or more.

4. Pigs.

These are conveniently considered separately.

Wart-hog	Common.
Bush-pig	Fairly common.

Among the smaller animals there are hares, spring-hares, rock-rabbits, porcupines, ant-bears, mongoose, and civet and serval cats. Guineafowl, lesser bustard, sand-grouse, francolins, and ground hornbills are all more or less common.

The game animals in the foregoing list, so far as concerns their behaviour in this area, are divisible into the following groups, depending on their need for meeting with water daily, irregularly, or not at all:—

1. Species ordinarily drinking daily: Lion, leopard, hyaena, ? other Carnivora; ? rhinoceros; waterbuck, impala, ? gazelles, ? wildebeest, ? roan, zebra, buffalo, elephant; wart-hog.

2. Species requiring water at intervals of two or three days, or rather more: Giraffe, greater kudu, ? rhinoceros; ? reedbuck, ? duiker; eland, kongoni.

3. Species which seem practically independent of water in the dry season: Lesser kudu; ? bushbuck, steinbuck, klipspringer, dikdik, suni; ? ostrich; bush-pig.

VII. Movements of the Migratory Game.

An attempt has been made to explain the movements of the species included in group B.3, above, in so far as they affect the area south and south-west of Sambala. This area is investigated regularly by the "mbuga" fly-round, the course of which is shown on the map (fig. 1). The round includes a temporary water pan in about the middle of the "mbuga," and passes through both bushed and open country round about it. The grass in much of the open country is rather long, and the water-hole dries about July.

A graph has been made of the numbers of the several species considered to be present in the round at any one time, these numbers being obtained from game seen, and the careful recording of spoor. As any animal crossing the round will do so at at least two points on the loop, it is considered that a reasonably accurate idea is obtained of the actual numbers of animals present. Also, as game is never very

abundant in the area concerned, it is possible to become familiar with parties, pairs, and individual animals in a way which would be impossible where game was very much commoner.

An examination of the curves obtained shows the following correlations :—

1. *Coke's Hartebeest or Kongoni.*

These animals do not appear to be much affected by shortage of water, in that they do not increase when other species are coming to drink at the water-hole between the start of the dry season and the time when it dries in July. On the other hand, the kongoni curve shows a striking inverse relation to the height of the grass. At the end of the long rains and during the early dry season, the grass is long, although at the end of that time it begins to lodge. As soon as the grass fires occur, the kongoni curve rises steadily to October. Then, except that a slight drop occurs when the last water-hole in the neighbourhood dries, it falls steadily as the grass increases its height through December, January and February, to the long rains.

The reason is believed to be that kongoni move over from the drier "mbugas" of Mapapu and Nafimu to the south-east for the young grazing about the Sambala River after the grass fires. It is known that kongoni are common in those "mbugas" during the long rains, when they are scarce at Sambala, and that they are scarcer in Mapapu-Nafimu during the height of the dry season. The reason for their departure at the onset of the long rains is believed to be that they fear the lions in the long grass, and therefore move back to the shorter-grassed areas of Mapapu-Nafimu. This conclusion is supported by the observation of Roosevelt and Heller in other parts of Africa, and by native opinion here.

2. *Eland.*

The eland curve in general follows that of the kongoni, but in addition rises slightly when animals are drinking at the water-hole in the "mbuga," where eland also are known to drink. They therefore seem to respond to both young grazing and presence of water, and are scarce in the long rains, when the grass is long. They commonly come out to graze in the "mbuga" about half an hour before sunset.

3. *Zebra.*

The main zebra movement appears to be correlated with water presence or absence, and they do not appear to be particularly attracted by young grazing. The first shower of rain, and particularly the start of the short rains, seem to cause a great increase in zebra everywhere about Sambala and not only in the "mbuga" round. After the first shower they are very common in the *Berlinia-Brachystegia* wooding to the north. It appears as if they will invade an area if grazing is universally abundant, but will not seek out small areas where local good grazing is to be had.

4. *Roan Antelope.*

Examination of the roan curve does not show any striking correlation with either grass or water. The reason is perhaps that this is rather typical roan country, some individuals living permanently in it and others casually moving through. It is known definitely that an old bull, a pair, and a lone smaller individual, have been resident in the area continuously for at least a year.

5. *Buffalo.*

Buffalo seem to appear mainly for water and casually at other times. A pair remained in the area during the last long rains.

6. *Elephant.*

With one exception, when they passed through in the late dry season, elephant have always come for the water at the pool in the "mbuga." During the early dry

season they are numerous and their visits frequent, so that they are an important factor in the drying of the water. Tracks of about 40 were counted on one occasion. Later they drink at Wa'amachthla and other waters to the north. Their home is in the thicket immediately to the east of the Station.

7. *Ostrich*.

Ostrich are apparently independent of water. They leave the area when the grass is still fairly short during the short rains, and return either at the time of the grass fires or when the grass is lodged, a little before the fires. They breed here, and are very numerous about the late dry season. They seldom enter the bushy parts of the area.

On the whole, game is most common in the Sambala "mbugas" during the mid and late dry season and scarcest in the long rains, and in a general way it can be said that the same applies to the country north of Sambala, although that region is less intimately known from the game point of view.

VIII. Habits of Species likely to be Important Food of Fly.

Unfortunately almost nothing has yet been done on the direct relations of fly and the species of game, but it may be useful to describe briefly the habits in Sambala of some of the species which may subsequently be found to be important.

It is not yet known to what extent fly is active at night and in the twilight, in the presence of favoured hosts or under different conditions of hunger or different physical conditions.

Observations so far have been too casual and in no way quantitative. This subject is one to which it is hoped to give attention as early as is possible. It is obviously a matter of great importance in estimating the value to fly of largely nocturnal animals like elephant and buffalo, which drink at night in places where fly is often in strong apparent concentration. It is known that during the colder months of the year, fly is very unwilling to attack man either at night or in the early morning, but the effect of introducing hosts other than man has not yet been given a trial at those times of day.

However, it appears likely that the following species will be worthy of thorough investigation :—

1. *Giraffe*.

Owing to its acute vision, its height, and the ease with which it can gallop through long grass, the giraffe would not appear to suffer special danger from lions when the grass is long, and does not in fact desert the country about Sambala when the grass has grown high. Moreover, it has the habit of patronising certain beats for months or years on end, and its comparative independence of water allows it to keep to certain favoured places when other game have gone. It is active during the daylight hours, and its large size makes it very conspicuous. These facts suggest that the giraffe may be an important food of the fly.

2. *Wart-hog*.

These animals are also diurnal, and drink at all hours, often from 10 o'clock to mid-day. They go about singly, in pairs, threes, or small family parties. They seem to drink daily, and are of general importance in the Sambala area because of their habit of tunnelling into the ground and so keeping open water-holes which would otherwise have become dry. During these operations, and while they are bathing in and drinking the water, they must be very much exposed to the attacks of flies, and their short tails and their almost hairless skins can offer little protection.

Mr. Burt and I have sometimes observed that we had smaller catches of fly than usual when wart-hog had just been chased away from a place. Flies are commonly found on wart-hog that have been shot. Jack (1914) reached similar conclusions.

3. *Rhinoceros*.

During the dry season rhinoceroses are little in evidence in Sambala, and seem only to leave the thickets at night in order to drink at distant water-holes. During the rains they are more often seen in the open in the early morning and late afternoon, when they are very conspicuous on account of their size and the speed of their progress. To what extent fly can feed through the skins of these animals is not known. A rhinoceros shot in *Berlinia-Brachystegia* wooding at 10 a.m. was carrying 37 male and 7 female flies, at a time when with man as bait only about 15 flies could be caught in half an hour. A rhinoceros shot in thicket had no fly. Although rhinoceroses are not very numerous, they are usually found alone, in pairs, or three together, and because they do not congregate in larger numbers, a few individuals must cover a good deal of country daily and so be potentially important as food of fly.

4. *Roan Antelope*.

In Sambala, a few individuals and pairs of this species have acquired very regular habits, continually passing and standing about in small open places in glades and valleys along their definite paths between the wooded areas and the grazing in the open "mbuga." They are to some extent diurnal in habit, and drink rather later in the early morning than many other species. They are also large, conspicuous, and not thickly haired, and the tail cannot be very effective in keeping off fly. On the whole it seems likely that they are of definite significance in the local tsetse problem.

IX. The Distribution of *Glossina morsitans* in the Area.

The Western Kondoa fly belt extends westwards from the Bubu River a distance of about 50 miles to just beyond the Kondoa-Singida border. It is bounded on the north by the open Mangati Plains and on the south and south-west by country more or less settled by natives, into which region it is said to be advancing year by year. It is also stated that the fly is advancing into Singida and that Sambala and the country about it were formerly free from fly. Sambala is situated approximately at the centre of the belt.

Reconnaissances have shown that fly is apparently commonest in the area north and north-east of Sambala. In certain areas within the belt it is extremely scarce, even though these areas are characterised by the tree species (*Acacia kirkii*, etc.) associated with apparently very thick fly elsewhere. Such a fly-scarce area is found to the south and south-east of Sambala, including the country of Mapapu and Nafimu, although fly appears to be common immediately to the north of it in rather similar country. The north-west corner of this area appears on the map.

The reason for the scarceness of fly within it is not understood, but perhaps it is in association with the large size of the area in relation to the small piece of *Berlinia-Brachystegia* wooding in contact with it.

The fly belt is also much dissected, especially in the south and west, by great blocks of thicket. The Samba area, between 10 and 20 miles south of Sambala, seems peculiar in that fly, which is not very common, is apparently found in any numbers in the more or less thicketed valleys only, and is very scarce in the *Berlinia-Brachystegia*.

As indicated on the map, fly is commoner to the north, scarcer to the south-west, and very rare to the south-east. The fly to the north is separated from the Station by half a mile to a mile of thicket, which it does not penetrate to any great extent. From the east and west ends of this thicket strip, tongues of thicket extend northwards for about a mile on each side. This disposition of the bush has the effect of enclosing

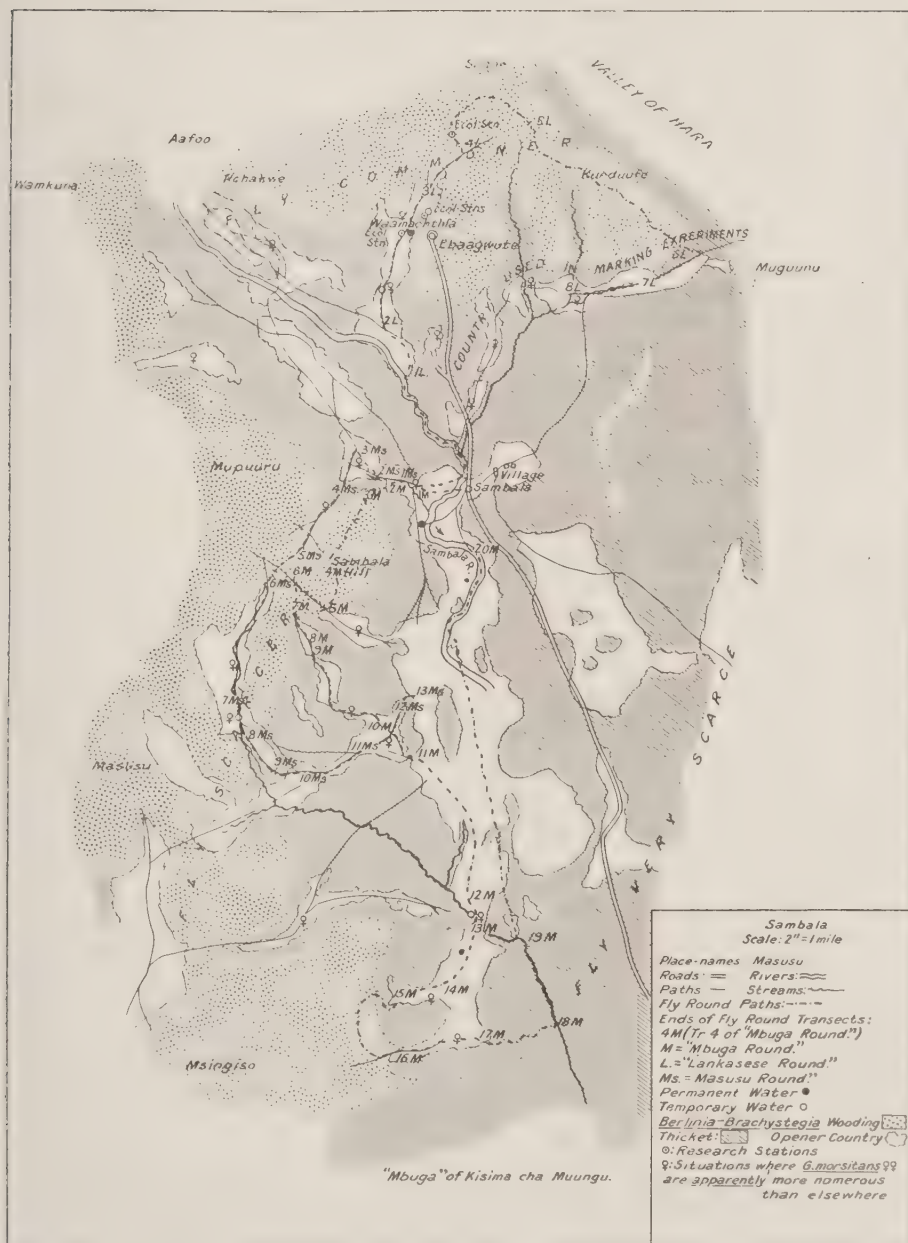


Fig. 1. Sketch-map of Sambala area, showing types of wooding and the fly-rounds.

on three sides the thick fly immediately north of the Station, and the area is therefore a useful one for carrying out experiments with marked flies. Northwards from this area the *Berlinia-Brachystegia* extends for a distance of 8 or 9 miles to the Mangati Plains, fly becoming gradually scarcer all the way.

Until February of this year a 15-mile fly-round (the old Lankasese round) tapped this area, the Hara valley, and the Lankasese country up to 6 miles north-east of Sambala, where fly is thick. The mean catch from this round was 436 flies, and the extremes 755 and 194 respectively. Owing to pressure of other work, this round was cut down at the end of February, and its course after that time is shown on the map.

The area to the south-west is separated from that to the north by the thicketed Sambala River, but is in contact with somewhat thicker fly to the north and north-west; on the east and west of it fly is very scarce. The *Berlinia-Brachystegia* wooding is of a generally poorer type. The area is explored by the "mbuga" round, which is about 12 miles long. The mean catch on this round was 64 flies, and the maximum and minimum respectively 131 and 13.

In addition, a supplementary round (Masusu round) was carried out once in 10 days immediately after the "mbuga" round from December to July, 1928-29. Both these rounds are shown on the map.

The rest of the country in the immediate neighbourhood was examined by frequent local reconnaissances.

X. Seasonal Variations in apparent Fly Density and Condition.

From the fly-rounds carried out from May 1928 to September 1929 there emerge the conclusions given below. It must be borne in mind that, as pointed out by Lloyd & Johnson (1927), the data obtained are capable of indicating the density-activity complex of man-coming flies only, and that no more than this is claimed for them.

1. Fly was most abundant in August and September, and late January to early March; that is, in the mid dry season following on the cold spell, and in the short dry season. Fly was least numerous in July, at the end of the cold spell.

This result, however, does not mean very much, because if the rounds had been planned to pass only through *Berlinia-Brachystegia* wooding, for example, the maximum would have been in March and the minimum in November—at the start of the long rains and in the late dry season respectively. The interpretation of these facts will be considered later.

2. Arising out of the above, it may here be remarked that fly is relatively scarce in "mbugas" and other situations outside *Berlinia-Brachystegia* wooding from the end of the long rains through the cold spell. From the end of the cold spell it increases greatly in such situations and less markedly in the *Berlinia-Brachystegia* wooding, where in 1928 it subsequently fell to a low level during the late dry season. In the late dry season, fly outside *Berlinia-Brachystegia* also shows a decrease. From the start of the short rains fly increases greatly both in the *Berlinia-Brachystegia* wooding and outside it. At the onset of the long rains fly begins to show a definite decrease in "mbugas," but a rise in the *Berlinia-Brachystegia*. From then on there is a general decrease in fly, which is most marked in the "mbugas."

These facts are brought out in the table on page 505 which shows the relations of fly in *Berlinia-Brachystegia* to that in other country. It will be noticed that even the small numbers obtained from the "mbuga" round show a general correspondence with the others.

While, therefore, there does not seem to be anything in Sambala comparable to the seasonal concentration of fly and evacuation of *Berlinia-Brachystegia* referred to by Shircore, Jack and Swynnerton, in other parts of Africa, there would appear to

Apparent Relative Diminution of Fly in "Male Areas" (mainly Berlinia-Brachystegia) during the Mid and Late Dry Season.

Seasons	Wa'a-machth-la "fem. flies per reading	Saane hill "male area," flies per reading	Per cent. in "male area" of both combined	No. of readings	Old Lan-kase Round, flies per reading	"Male areas" in above, flies per reading	Per cent. in "male areas"	No. of readings	"Mbuga" Round, flies per reading	"Male areas" in above, flies per reading	Per cent. in "male areas"	No. of readings
End of long rains ...	59.5	60.5	50.4	2	—	—	—	—	—	—	—	—
Early dry season ...	16.9	34.9	67.3	14	337.8	94.9	28.1	10	29.1	7.4	25.4	15
Mid dry season	39.6	30.6	43.0	16	477.4	100.0	20.9	15	86.9	7.6	8.7	16
ate dry season ...	25.7	14.5	36.1	6	404.7	56.8	14.0	6	51.3	4.8	9.4	6
Short rains ...	54.6	28.9	34.6	7	410.9	93.0	22.6	7	79.3	12.7	16.0	10
Short dry season ...	79.25	46.75	37.1	4	643.5	157.0	24.2	2	95.0	12.75	13.0	4
Long rains ...	52.0	56.3	52.0	11	—	—	—	—	62.2	12.0	19.3	10
Early dry season ...	10.6	30.1	73.8	12	—	—	—	—	40.1	10.1	25.2	15
Mid dry season	29.25	29.25	50.0	4	—	—	—	—	114.5	10.0	8.7	4

be an *apparent relative diminution* in that type towards the end of the dry season, although at the start of the apparent relative diminution, in August, the numbers of fly taken in *Berlinia-Brachystegia* are rising like those elsewhere.

3. "Young" (soft) flies are most numerous when fly in general is most numerous, that is in August–September and late January to early March; but soft flies *per cent.* are high temporarily shortly after the long rains as well as at these times. The proportion of soft flies is lowest at the end of the cold spell, and they seem to show a drop at the return of the rains following on the mid dry season, the late dry season, and the short dry season, respectively. The curve of soft flies *per cent.* shows a range of variation from 0 to 25 per pair of days on the "mbuga" round, and from 0 to 15 on the Lankasese round.

4. Pregnant females are not sufficiently numerous to justify any remarks.

5. The female percentage appears to rise more or less steadily from the cold spell into the mid dry season, after which it remains more or less steady or variable in the late dry season, and shows a drop at the start of the short rains. When these are ending, in January, the female percentage rises again into the short dry season in February–early March. With the return of the rains it drops again, and remains fairly low or falls even lower until the next mid dry season.

This, however, includes the young flies; and since male and female young flies, being unfed, are probably equally inclined to attack man, and are in fact caught in roughly equal numbers, it is perhaps better to consider the percentage of females in the old flies alone.

This curve shows an almost exact correspondence with the curve of the total female percentage just described. It also agrees with the young fly *per cent.* curve fairly well, except that it does not rise appreciably shortly after the long rains.

XI. The Anatomy of the Fly Belt about Sambala.

A. "Female Centres."

Reference to the map shows the distribution of the "female centres" in the neighbourhood of the Station. The term "female centres" was used to describe *those situations in which female flies readily attack man*. Their area is usually rather small, and they frequently show a greater or less *apparent concentration* of fly relative to the surrounding country.

A consideration of their distribution shows that they do not occur anywhere in large blocks of homogeneous bush. They occupy such situations as the neighbourhood of water-holes, cross-paths, bottle-neck passages between hills or through thickets, and narrow, sloping valleys between hill spurs; *but always the situations in which they occur are from their nature and the nature of the surrounding country regularly used by game*, for at least a part of the year.

Female centres may be permanent, sub-permanent, or temporary; but those that disappear during the cold spell or in the rains appear again afterwards in the positions they occupied before.

An analysis of game spoor recorded on fly-rounds and reconnaissances shows that game is at least as frequent in those transects including female centres as it is elsewhere, and that generally it is very much more frequent in such transects. But if the *heart* of the female centre is considered alone, it is evident that within the few square yards which it may cover game is very much more frequent than in any similar-sized area of less specialised country elsewhere.

Female centres, then, seem to be the best places to which fly could go to await the passage of its hosts.

B. "Male Areas."

In contrast to the "female centres," the "male areas" of the Sambala neighbourhood are spread over broad stretches of more or less homogeneous *Berlinia-Brachystegia* wooding.

Within them the percentage of female flies is usually appreciably lower than in the female centres, this sex being practically absent except towards the end of the dry season.

Soft flies also are rare in *Berlinia-Brachystegia* wooding, and ordinarily relatively numerous in female centres. This fact is remarkable, since from empirical considerations based on the hardness of the ground in the "mbugas," and from the fact that *Berlinia-Brachystegia* is known to harbour substantial numbers of puparia while "mbugas" are not, it seems likely that the male areas in the *Berlinia-Brachystegia* may form the principal breeding-grounds of fly. (On the other hand, it yet remains to make exhaustive search for puparia in "mbugas.")

As an example showing the distribution of soft flies, one may take the old Lankasese round during the period when it was carried on in its complete form, from 12th June 1928 to 5th February 1929. There were four male area transects on this round, two through *Berlinia-Brachystegia* wooding and two through *Acacia stenocarpa* country.

Number of flies in whole round	...	...	...	11,928
Number of soft flies in whole round	...	...	...	1,182
Percentage of soft flies	...	...	...	9.9
Number of flies in male area transects	...	...	...	3,342
Number of soft flies in male area transects	...	...	...	173
Percentage of soft flies	...	...	...	5.2

There are thus proportionately fewer soft flies in the male areas than in the rest of the country, which includes transition zones, female centres, and other types.

C. Fly-infested Country other than the Female Centres and Male Areas.

Since a female centre is not necessarily contiguous with a male area, it follows that there may be transitions between them. Whether these simply consist of a mixture of flies from female centres and male areas, or whether the transition zones are definite factors in the ecology of the fly, it is not at present possible to say. At any rate, it can be said that in apparent fly density, female flies per cent., and the percentage of young flies, transition areas act as if they were composed of a simple mixture of the fly communities between which they lie.

In certain areas along the course of the Sambala valley, in the Hara valley to the north-east, in some of the Pamumu-country north of the scarce-fly area discussed above, and doubtless elsewhere, fly occurs in greater or lesser apparent density over rather large areas with a rather high percentage of females and young flies. Within such areas it may also congregate about water-holes and other favourable spots to form small communities of the female centre type, and these broader areas are regarded, as will be explained below, as not differing essentially from the true, concentrated female centres already described.

In areas where fly is very scarce, the proportion of females is often high, sometimes as high as 50 per cent., as is often the case in open country where fly is probably unable to survive at all permanently. In general, also, the female percentage is higher on the "mbuga" round, where fly is scarcer, than in comparable vegetation communities on the Lankasese round, where it is commoner.

The foregoing account covers the main recognised fly communities of the Sambala area. It may be said that, except in the Samba area, which will be considered later, reconnaissances have lent general support to the observations near Sambala. That is to say, reconnaissance has shown that there is nearly always a marked or slight

concentration of flies about small valleys and water-holes, except sometimes in the cold weather about June, these flies showing a high percentages of females ;] and that females are apparently scarce in *Berlinia-Brachystegia* wooding.

The relations of the female centres and male areas of the Lankasese round are shown on a graph (fig. 2).

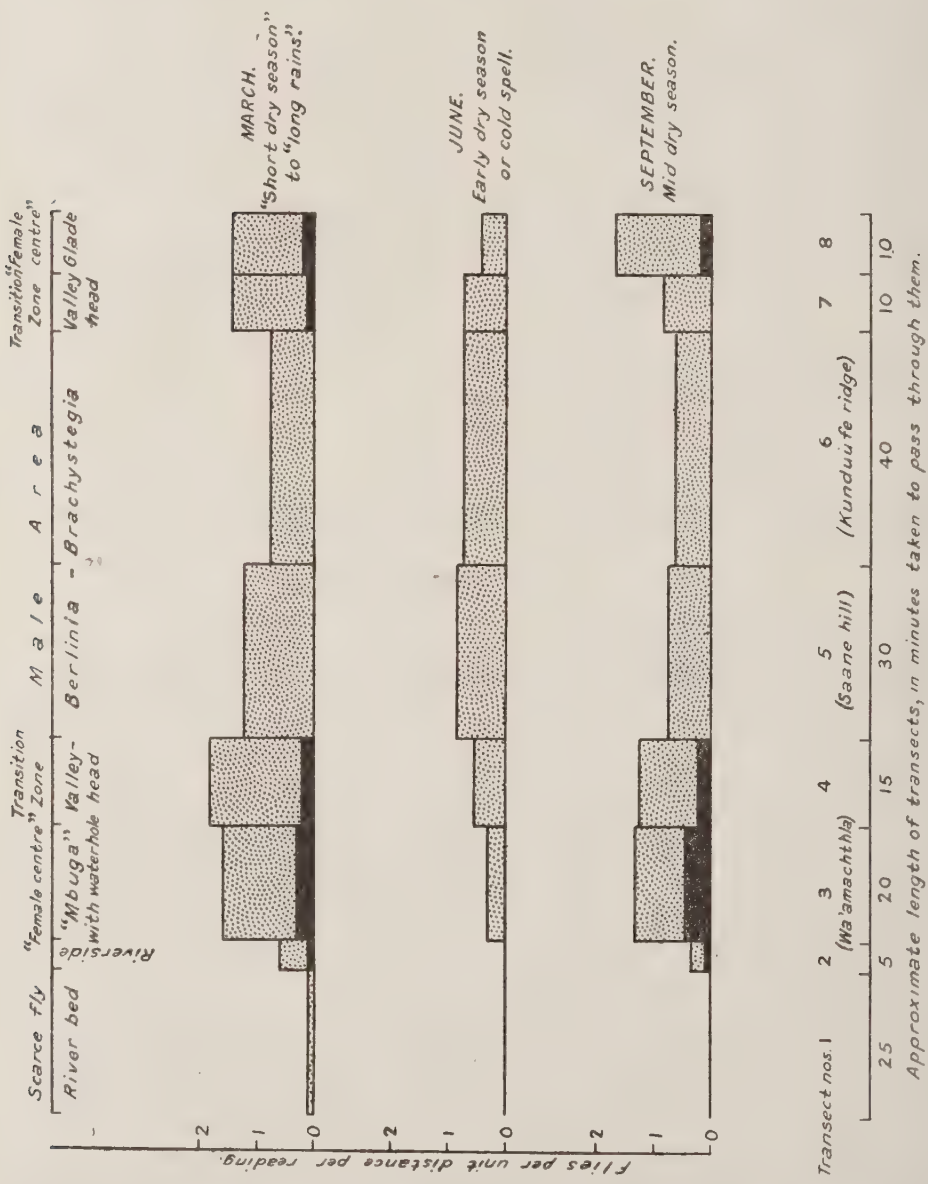


Fig. 2. Apparent fly-density in place and time: the Lankasese Round, Sambala. ♂♂ stippled; ♀♀ black.

XII. The Meaning of the Fly Distribution at Sambala. The Feeding-ground Concept.

It is well known that tsetse puparia in captivity produce either an equality of sexes or a slight excess of female flies; but that in nature, collecting with man as bait, the proportion of females is generally below 50 per cent.

Lamborn (1915) suggests that the females are driven into retirement by the persistent attentions of the males, which conversely are active partly because of their eagerness to meet with the opposite sex. That is to say, a catch of flies is ordinarily composed of (i) hungry males, (ii) hungry females, and (iii) males not hungry, but searching for females.

Fiske (1920), working on *G. palpalis*, notes that other animals attract a higher proportion of females, and argues that man is not a preferred host.

Swynnerton (1921) records cattle as attracting more females than does man. He also suggests that the male clusters observed in the grass were awaiting the passage of females on host animals.

Lloyd (1912) observes that if flies are allowed to bite before being captured, males and females are taken in approximately equal numbers.

Fiske and other workers also assert that the female percentage is raised when fly is starving.

It therefore seems probable that (i) females come to man mainly to feed; (ii) man is not a preferred host; (iii) males come to man to feed and also for some purpose other than feeding.

Lamborn supports the theory that females avoid males by his observation that females are found in higher proportion in scarcer fly or at the periphery of a fly belt also.

The observations of Lamborn, Fiske, and Swynnerton, suggest that flies should ordinarily show higher percentages of females in (i) areas of low fly density, and (ii) localities where animal hosts are permanently or temporarily scarce.

These considerations caused attention to be focussed on the female centres in the Sambala area, since these showed: (i) A high female percentage in relatively dense fly, and (ii) a high female percentage where game passage was unusually frequent.

To find an explanation in agreement with the views of the workers named above, it was suggested that female centres represented permanent or semi-permanent concentrations of fly in situations favouring frequent passage of animal hosts; and that the more active males drifted away from them in pursuit of passing game. The proportion of females, it was argued, would thereby be increased to over 50 per cent. among the remaining flies; and a part of this increase was supposed to be apparent with man as bait, in spite of the regular passage of game.

At the same time it was suggested that male areas, where fly was often apparently scarcer, were composed of the males which had drifted out of the concentrations and had not yet returned.

This conclusion seemed to receive some support from the presence of young flies in female centres, which seemed to suggest that they were real concentrations of fly. On the other hand, it was also known that breeding occurred to an appreciable extent in the male areas.

At the suggestion of the Director of Tsetse Research, some collecting with cattle in female centres and male areas was carried out. Before the results are given, it is wished to emphasise very strongly that they are not intended as a serious experiment to show the effect of bait cattle on fly. They were used for a particular

purpose—to test the reality or otherwise of the apparent concentrations observed—and are intended to do no more than settle this point.

Summary of Results with Cattle in Male Areas.

January to May, 1929.

Cattle.		Man.		Remarks.
Flies.	Females per cent.	Flies.	Females per cent.	
115	19.1	70	7.1	Collecting with man in most nearly comparable circumstances.
398	22.1	357	1.7	
27	44.4	17	5.9	
28	57.1	15	13.3	

July to September, 1929.

Cattle.		Man.		Remarks.
Flies.	Females per cent.	Flies.	Females per cent.	
17	0	36	0	Collecting with man in comparable circumstances.
38	2.6	31	0	
8	0	23	0	
37	8.1	36	5.6	
59	3.4	61	1.6	
67	4.5	63	0	
8	0	4	0	
38	5.3	37	0	
43	4.7	44	0	
12	0	15	0	

(The relative total catches cannot for various reasons be submitted to direct comparison.)

The results above can be summarised as follows :—

				Totals.	Females per cent.
Period 1—					
Cattle	...	...		518	26.6
Man	...	...		459	3.1
Period 2—					
Cattle	...	...		330	3.9
Man	...	...		347	0.9

The effects of introducing cattle into female centres were more doubtful ; the effect seemed to be very slight, but it was more difficult to get comparable results.

The foregoing results seem to show that cattle can raise the percentage of females in male areas considerably above the normal at certain times of the year, and slightly at other times.

At any rate, they are sufficient to show that the females are not *necessarily* any commoner outside male areas than inside them, and that, at some times of the year at any rate, they may possibly form an appreciable proportion of the flies in male areas, although not appearing to man.

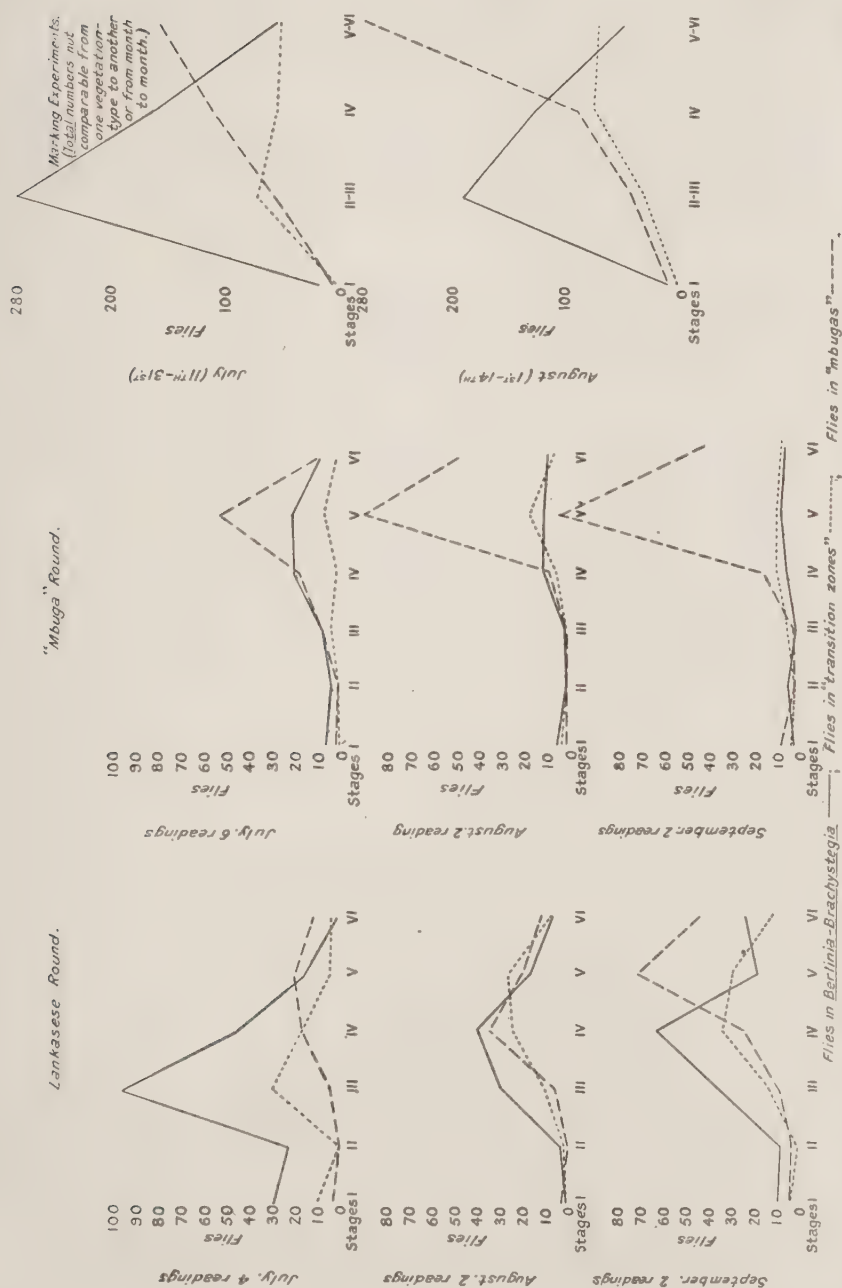


Fig. 3. Hunger of flies. Note.—1. Fly is most hungry in "mbuga," least so in *Berlinia-Brachystegia*; 2. Fly becomes hungrier at the start of the mid dry season (August); 3. At the same time it apparently becomes more numerous (per reading); 4. At the same time there begins an apparent relative diminution of fly in *Berlinia-Brachystegia*; 5. Fly is still in general less hungry in this type than outside it; 6. The start of the mid dry season was characterised by a major and increasing rise in temperature and evaporation rate.

In order to cover the foregoing observations it was then suggested: (i) That females might possibly be found to exist in equal or approximately equal numbers in male areas and female centres respectively, but that in female centres they were more inclined to show themselves; (ii) that this might be due to greater hunger of flies in female centres; (iii) that female centres were the *feeding grounds*, and male areas the *home*, of the fly.

This suggestion is strikingly similar to the conclusion of Fiske (1920), who, working on *G. palpalis*, states that "every second or third day the flies of both sexes undertake food-hunting flights," in which they leave more sheltered localities in order to "range along the lake shore or other favoured route in search of the sluggish amphibian animals on which they principally feed."

XIII. Comparative Statistics on Hunger of Flies from the Field.

As a first step in the investigation of the feeding-ground concept, it was necessary to know whether flies from female centres were actually hungrier than those in male areas.

To begin with, therefore, 80 male flies from the Saane Hill male area and 80 from the Wa'amachthla female centre (see Map) were submitted in March to Mr. Potts, who very kindly dissected and examined 20 of each batch.

From this examination it was quite apparent that flies from the male area were in much better condition than those from the female centre.

These internal examinations were not continued, as it was observed that there was also considerable difference in the external appearance of the respective batches of flies, and reliance was therefore afterwards placed on the system of grading described on pp. 494-5. This system was used on fly-rounds from July to September 1929, and during that time at least it was quite apparent that fly was everywhere hungrier in female centres, repleter in male areas, and in general intermediate in the transition zones.

These facts are brought out on the hunger graphs (fig. 3) of the "mbuga" and Lankasese rounds, which also show the beginning of the apparent relative diminution of fly in *Berlinia-Brachystegia* (male areas), at the start of the mid dry season following on the cold spell.

Further examination shows that, at the same time as the apparent relative diminution in *Berlinia-Brachystegia* begins, fly is becoming generally more hungry; but that *it is still less hungry in the Berlinia-Brachystegia than in the "mbugas" and transition zones.*

Finally, the curves also show that at the same time fly has become more numerous; and we know from what has been said before that the female and fresh fly percentages have both risen since the cold spell. The change from the hot to the cold spell is seen from physical data kindly supplied by Mr. Burt to be correlated with a marked and sustained rise in temperature and evaporation-rate as from about 1st August.

A graph (fig. 4) of Mr. Burt's fly catches about this time shows that there is close correlation between the major physical changes mentioned, the rise in fly numbers generally, and the beginning of the apparent relative diminution of fly in the male areas.

The grading according to external appearance was incidentally employed in fly-marking experiments during July and August, and for a few days at the end of September. From the graphs of these most of the facts described already can be seen; the relative numbers of flies taken respectively in *Berlinia-Brachystegia* and elsewhere are not, however, comparable, so that the apparent relative diminution in male areas cannot here be shown.

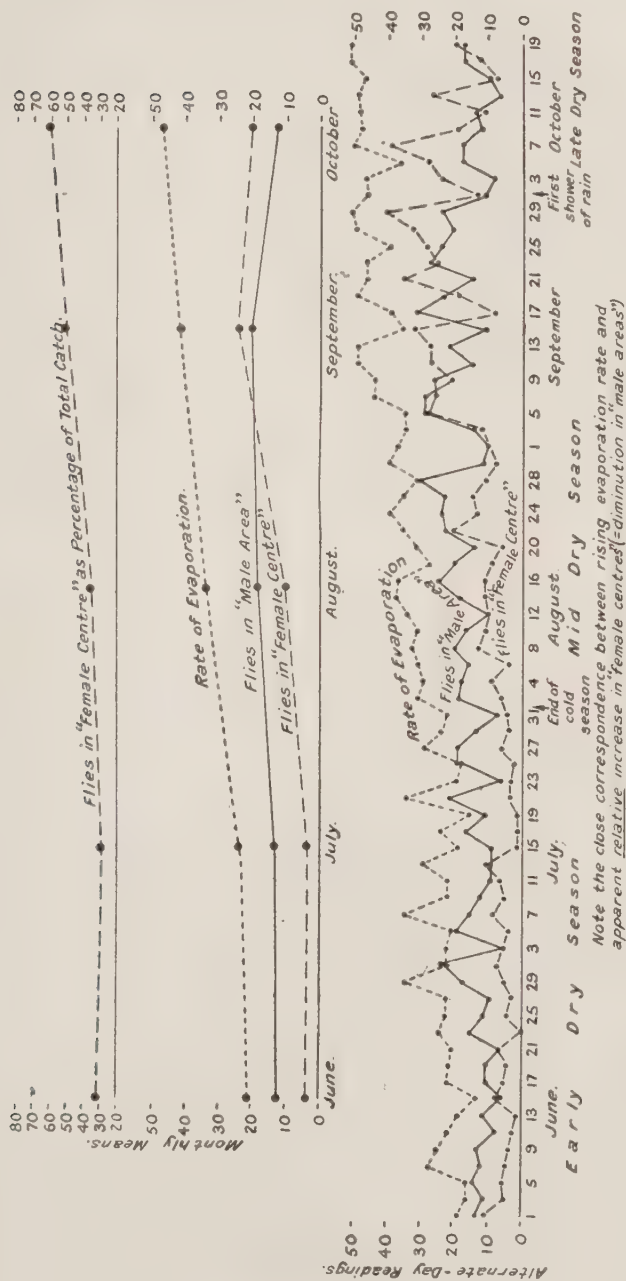


Fig. 4. Fly and evaporation rate—Mr. Burt's figures.

XIV. Further Considerations on the Feeding-ground Concept.

It is now desirable to review the position of the feeding-ground concept at this stage.

It has been ascertained that flies in female centres are in general hungrier than those in male areas. There are therefore only two possibilities to distinguish: either (i) flies are hungry because they are in female centres; or (ii) they are in female centres because they are hungry.

In other words, (i) are the physical or biotic conditions in female centres such that flies by drifting accidentally into them are thereby rendered hungry by acceleration of the processes of digestion, or by failure to meet with food; or (ii) do flies purposelessly or otherwise drift from male areas to female centres under stimulus of approaching hunger, returning to male areas when satisfied?

While certain of the observations described above seem to throw light on this choice of alternatives, it seems better to leave them for the present until after discussion of the field experiments which follow.

These field experiments were designed solely to throw light on the matter at issue, although as stated on p. 495 they have not altogether achieved their object.

In spite of this, it is considered justifiable to give some account of the experiments, as indicating a line which could be followed up to produce a definite result one way or the other; and because such matters as the histories of flies several times recaptured are of some intrinsic interest.

XV. Field Experiments.

A. "Catching-out" Experiments.

If fly is *not* drifting aimlessly through the bush, and if on the contrary hungrier flies are moving from a large diffuse male area to a small compact female centre, then the female centre ought to show a definite, steady flow of arriving flies not, or not so much, apparent in the male area.

To test for such a drift the "catching-out" experiments were devised. It will be remembered that in any catch flies were conceived to be divisible into three categories: (i) flies present and eager to attack; (ii) flies present but reluctant to attack; (iii) flies arriving. It was suggested that in a standing catch in any one spot a curve of flies taken per unit time should show: (i) an initial, high, more or less flat section composed chiefly of flies present and eager to attack, but including the first reluctant and a few arriving flies; (ii) a steeply or gently falling section composed of diminishing reluctant flies and some arriving flies; (iii) a practically flat section of arriving flies going on indefinitely through the day.

The earlier experiments to test for these hypothetical phenomena were of only about an hour's duration, and gave falling curves. Subsequently, three-hour standing catches were carried out, and these gave more interesting results. The experiments were carried out in co-operation with Mr. Potts.

The method employed was to select two stations about 10 yards apart in a suitable situation, and to move from one to the other every 2 minutes. In approaching the scene of operations every care was taken to catch-off following flies, the party halting in some cover a short distance from the selected site to complete the process, and then proceeding rapidly to the spot to begin the catch; 6 natives and 2 Europeans was found to be the best number for the experiment. Flies were caught, marked, and released, note being made of the sexes, and the half-minutes in which they were taken.

The results of six experiments carried out in this way at the Wa'amachthla water-holes (see Map) are set forth below ; for the sake of brevity quarter of an hour catches are given instead of half-minute ones.

No.	Date.	Time.	$\frac{1}{4}$ -hrs.											
			1	2	3	4	5	6	7	8	9	10	11	12
1	14.iii	9.55 a.m. -12.55 p.m.	51	24	16	9	7	14	8	10	7	7	5	4
2	16.iii	1.43 p.m. -4.35 p.m.	24	15	6	9	4	4	4	2	1	1	5	—
3	17.iii	2.46 p.m. -5.46 p.m.	27	16	11	12	5	5	2	3	4	4	1	4
4	7.iv	3.1 p.m. -6.1 p.m.	53	17	21	12	19	31	11	6	12	15	14	7
5	13.iv	10.28 a.m. -1.44 p.m.	20	7	4	3	3	3	4	5	3	1	1	3
6	27.iv	1.24 p.m. -4.24 p.m.	25	16	3	4	5	5	2	10	10	9	4	4

While these results are admittedly very few and need development and repetition, it is possible to make the following comments on them :—

(i) In expts. 2, 3, 4 and 6 fly definitely does not show any steady falling away after the first hour or hour and a half.

(ii) Expts. 1 and 5 seem to show a falling-off about mid-day ; conversely, expt. 6, begun shortly *after* mid-day, begins with a small initial "burst" relative to the after-part, and shows a considerable rise during the afternoon.

(iii) In short, apart from a falling-off at mid-day, the experiments show that fly does not cease being caught during the three hours ; and it seems reasonable to suppose that the second half of the experiment every time represents arriving flies.

Two more experiments were carried out on exactly similar lines. One was in transect 8 of the Lankasese round (see Map), a typical female centre where fly is ordinarily fairly common, although at the time of the experiment it was scarcer. The other was in scarcer fly in transect 11 of the "mbuga" round, a female centre about the crossing of two game-paths..

The results of these experiments are summarised in the same way as the others.

Place	Date	Time	$\frac{1}{4}$ -hrs.											
			1	2	3	4	5	6	7	8	9	10	11	12
Trans. 8, L. Round	22.vi	3.27 p.m. -6.27 p.m.	25	4	5	3	1	1	3	8	1	1	1	2
Trans. 11, M. Round	31.v	2.56 p.m. -6.11 p.m.	13	2	3	2	6	4	0	3	3	0	0	2

These experiments may be said to confirm those carried out at Wa'amachthla, in that they represent female centres in which fly does not cease arriving during the progress of the catching. It is worthy of note that in both these experiments flies continued to arrive after sunset.

In contrast to these results in female centres, very different ones were obtained in such experiments as were done in male areas. Once more, it is emphasised that more experiments are necessary for confirmation.

The male area experiments were carried out in representative portions of the Saane-Ebaagwute-Kunduufe *Berlinia-Brachystegia* wooding north of Sambala (see Map).

Place	Date	Time	$\frac{1}{4}$ -hrs.											
			1	2	3	4	5	6	7	8	9	10	11	12
Ebaagwute	14.vi	2.50 p.m. -5.50 p.m.	1	1	1	1	0	3	0	0	1	0	0	0
Kunduufe	18.vi	2.26 p.m. -5.26 p.m.	9	2	1	1	1	2	2	0	0	0	0	0
Saane	15.vi	2.2 p.m. -5.2 p.m.	6	3	3	0	0	2	0	0	1	0	0	0

From these figures it is evident that flies arrived very spasmodically in the male areas during the experiments, and towards the end ceased to arrive at all.

In the Kunduufe and Saane experiments fly-boys were sent out radially from the place of catching immediately after the close of the experiments to collect any flies which might be lurking in the neighbourhood. In the Saane experiment they caught in this way 6 flies between 30 and 100 paces (3 flies at 30 paces) from the scene of the experiment, and in the Kunduufe experiment, 6 flies at from 50 to 100 paces. That is to say, in these two experiments, after no flies had been taken for about the last hour, flies were readily obtained within a hundred paces of the scene of operations, and it is reasonable to assume that they had been there all the time and simply disinclined to attack.

B. Marking and Recapturing Flies.

After the abortive experiments of April, May and June referred to on p. 495, the main experiments were begun on 30th June and continued up to 14th August, when they had to be abandoned owing to pressure of other work.

The original purpose was (i) to find out whether hungrier flies marked in male areas appeared sooner in female centres than did less hungry ones, and (ii) to gain general information on the habits of individual flies by continued recapturing and releasing. Thanks are due to Mr. Burt for recapturing and noting flies from these experiments caught by him in the progress of his ecological work in Wa'amachthla "mbuga" and on Saane hill.

The southern slope of Kunduufe hill was chosen as a suitable male area for the experiments, and, as representing female centre and transition conditions, the path from the Ebaagwute road to transect 8 of the Lankasese round was employed (see Map). Marking was carried out on most afternoons during the period in question, usually from 3.0 to 6.0 p.m., and flies from previous markings were recaptured, re-marked, and released in the progress of the work. By using the clock system of re-marking described on p. 495, a fly once caught for the second time could thereafter be recognised as an individual, and by a system of book-keeping trace of its history could be kept.

The disposition of the country has already been described (p. 495), and apparently it was effective in limiting the range of flies, since at some times every third fly encountered on Kunduufe south slope had been marked before.

In initial marking it was not considered necessary to distinguish stage III flies from flies in stage II, this stage being comparatively rare and therefore probably

short-lasting (for description of the stages, see pp. 494-5). Nor was it possible to distinguish accurately, without killing the flies, between stages V and VI, except in certain very obvious cases.

In the course of the experiments about 3,500 flies were originally marked. Rather more than 700 of these were recaptured once, over 100 were caught a third time, 15 flies 4 times, 1 fly 5 times, and 1 fly 6 times. The recaptures therefore totalled about 20 per cent. Incidental information showed that few flies were recaptured more than 60 days after marking, but 1 male was taken 70 days, and another 75 days, after the original marking. Another interesting case was of a young female recaptured still soft and unfed 4 days after marking, having travelled from a male area to a female centre. A female fly was recaptured about a month after marking in a female centre 5 or 6 miles to the north.

The general hunger statistics from these experiments are dealt with in a graph (fig. 3) and have already been discussed (p. 512). The main results of the experiments bearing on the flies leaving male areas for female centres or transition zones are summarised below.

It is realised that these figures are too small to be considered seriously as scientific evidence in support of the feeding-ground concept, but they seem sufficiently interesting to reproduce, and they are consistent so far as they go.

Marked	Recaptured	Condition	First 3 days	Afterwards	Ratio
1. Male area ...	Female centre and transition	Hungrier ...	21	27	1 : 1.3
		Repleter ...	27	82	1 : 3.0
2. Male area ...	Male area ...	Hungrier ...	20	51	1 : 2.55
		Repleter ...	57	118	1 : 2.1
3. Female centre and transition	Male area ...	Hungrier ...	11	23	1 : 2.1
		Repleter ...	5	14	1 : 2.8
4. Female centre and transition	Female centre and transition	Hungrier ...	104	68	1 : 0.7
		Repleter ...	21	35	1 : 1.7

On the whole, there is a tendency to show that (i) hungrier flies appear in female centres and transition zones sooner than repleter ones; and (ii) that hungrier flies tend to remain in female centres for the first few days, and repleter ones to disappear until later. The results under 2 and 3 are too indefinite to say anything about.

It is now proposed to consider the flies with histories more or less known.

1. Cases against the feeding-ground concept.

These mainly consist of flies found in female centres and transition areas while still replete. For the sake of brevity it is proposed to use "miombo" for "male area" and "mbuga" for "female centre."

No.	Stage	Vegetation type	Days' interval	Remarks
34 ...	i-iii	Miombo	—	Fly twice visits mbuga when not hungry.
	iii	Mbuga	16	
	iii-iv	Miombo	2	
	v	Mbuga	18	
	iii	Mbuga	4	
15 ...	i-iii	Miombo	—	Fly visits mbuga when replete. (On the other hand it quickly returns.)
	ii-iii	Mbuga	1	
	iii	Miombo	1	

No.	Stage	Vegetation type	Days' interval	Remarks
32 ...	i-iii iii iii	Miombo Miombo Mbuga	— 8 2	Fly visits mbuga when still replete.
45 ...	i-iv iii iii	Mbuga Mbuga Mbuga	— 9 6	Fly at least twice visits mbuga when replete.
52 ...	ii-iii v i (red blood)	Miombo Miombo Miombo	— 5 5	Fly fails to leave miombo when hungry; subsequently almost certainly feeds in miombo.
64 ...	i iii iv-v	Mbuga Mbuga Mbuga	— 6* 6*	Fly visits mbuga when replete. *Exactly the same place.
73 ...	ii-iv* ii i-ii	Mbuga Mbuga Miombo	— 9 26	*Probably iv. Fly visits mbuga when replete.
78 ...	v iii v	Mbuga Mbuga Mbuga	— 8 4	Fly visits mbuga when replete.
99 ...	ii-iii iii v	Mbuga Transition Mbuga	— 2 6	Fly visits mbuga once when hungry and once when not. Does not return to miombo at once after the visit when replete.
100 ...	ii-iii ii iii	Mbuga Transition Mbuga	— 5 24*	Fly twice visits mbuga when replete. *Near transition.

2. Cases in favour of the feeding-ground concept, either directly or as indicating a place memory in flies.

No.	Stage	Vegetation type	Days' interval	Remarks
2 ...	iv-v i ii iv	Miombo Miombo Miombo Transition	— 2 1 25	Fly becoming hungry in miombo feeds <i>somewhere</i> and returns. Later it is found fairly hungry in transition area as if on way to mbuga to feed.
6 ...	iv-v v iv v	Mbuga Mbuga Mbuga Transition	— 2* 4* 1*	Fly (a) waits in mbuga while hungry, (b) seems to remember the place when hungry again. *Within 100 yards.
24 ...	i-iii iv iii iv	Miombo Mbuga Miombo Mbuga	— 4* 3 1*	Fly proceeds from miombo to mbuga when hungry, and returns when not. It uses the same spot in mbuga both times. *Same place.
37 ...	ii-iii iii iii i	Miombo Miombo Miombo Mbuga	— 13 1 9	Fly always found replete in miombo; also found recently fed in mbuga, suggesting it may feed there and digest in miombo.

No.	Stage	Vegetation type	Days' interval	Remarks
38 ...	v	Mbuga	—	Fly marked in mbuga, exact locality unknown. Taken in miombo 9 days after, feeding on man. Taken fairly hungry in miombo next day. Taken hungry in mbuga 2 days later; fed full on man. Taken in miombo 4 days later becoming hungry. Taken fairly hungry in mbuga within 50 yds. of last place 3 days later. Fed full on man.
	?-i ($\frac{1}{2}$ -fed)	Miombo	9†	
	iv-v	Miombo	1†	
	v-i	Mbuga	2*	
	iv	Miombo	4†	
	iv-v-i	Mbuga	3*	
		* Within 50 yards. † Not far apart.		
42 ...	?	Miombo	—	Fly originally in miombo (stage and date unknown) comes to mbuga when hungry and waits a day. Later returns to same spot when hungry again. * Same place.
	iv-v	Mbuga	2*	
	iv (-v)	Mbuga	1*	
	iv	Mbuga	6*	
53 ...	ii-iii	Miombo	—	Fly always replete in miombo, and always taken there in about the same place, even at long intervals. This suggests memory. *High on S. slope of Kunduufe, East Section.
	ii	Miombo	3*	
	iii-iv	Miombo	7*	
	iii	Miombo	20*	
58 ...	i-iii	Miombo	—	Fly found in miombo when replete, in transition zone when hungrier. *Same place.
	iv	Transition	2	
	ii	Miombo	20*	
	iii	Miombo	2*	
69 ...	ii-iv	Mbuga	—	Fly waiting 1 day in mbuga while hungry; subsequently after long interval returns hungry to same place. *Within 100 yards.
	iv	Mbuga	2*	
	v	Mbuga	1*	
	iv-v	Mbuga	28*	
75 ...	ii-iii	Miombo	—	Fly in miombo when replete, hungrier when in transition and mbuga.
	iv	Transition	5	
	iv	Transition	5	
	iv	Mbuga		
3 ...	iv-v	Miombo	—	Fly hungry in miombo proceeds to transition and waits 2 days. *Same transition zone.
	v	Transition	1*	
	v	Transition	2*	
10 ...	ii-iv	Transition	—	Fly becoming hungry in transition enters mbuga and waits 2 days.
	v	Mbuga	1	
	v	Mbuga	1	
11 ...	i-iii	Miombo	—	Fly remaining in miombo during digestion.
	ii	Miombo	1	
	iii	Miombo	1	
12 ...	v	Transition	—	Fly hungry in transition zone moves to mbuga and waits 1 day. *Within 100 yards.
	v	Mbuga	1*	
	v	Mbuga	1*	
13 ...	i-iii	Miombo	—	Fly becoming hungry proceeds slowly through transition to mbuga.
	iii-iv	Transition	2	
	iii-iv	Mbuga	1	
26 ...	v	Mbuga	—	Hungry fly waits 1 day in mbuga; when hungry again, returns, but not to same place.
	v	Mbuga	1	
	v	Mbuga	6	

No.	Stage	Vegetation type	Days' interval	Remarks
54 ...	? iv v	Miombo Mbuga Mbuga	— ?* 1*	Fly from miombo is or becomes hungry, descends to mbuga, and waits 1 day. *Same place.
61 ...	ii-iii iii iv	Transition Miombo Mbuga	— 4 3	Fly replete in transition zone proceeds to miombo; when hungry goes to mbuga.
66 ...	iv iv v	Miombo Mbuga Mbuga	— 3* 3*	Fly becoming hungry in miombo proceeds to mbuga, and probably waits 3 days. *Within 50-100 yds.
74 ...	iv i ii	Miombo Mbuga Miombo	— 3 6	Fly hungry in miombo visits mbuga; probably feeds there; taken later in miombo after another feed.
76 ...	iv iv iv	Mbuga Mbuga Mbuga	— 4 4	Fly visits mbuga at 4-day intervals, every time in stage iv. (Not in same place.)
81 ...	iv iv v	Mbuga Mbuga Sambala Station	— 4 1	Fly visits mbuga twice at 4-day intervals in stage iv; the second time it remains in mbuga and is carried into camp, probably on a car.
82 ...	i iv v	Transition Mbuga Mbuga	— 12 1	Fly waits about the same place in mbuga when hungry for 1 day.
94 ...	i iv v	Miombo Mbuga Mbuga	— 9* 1*	Fly travels along mbuga when hungry, but remains in it. *About 1 mile apart.
96 ...	iv iv iv	Mbuga Mbuga Mbuga	— 4* 8*	Fly visits mbuga when hungry at intervals of 4 and 8 days, twice at least to same place. *Within 50 yds.

3. Other cases against the feeding-ground concept.

No.	Stage	Vegetation type	Days' interval	Remarks
85 ...	ii-iv iv iii-iv	Mbuga Mbuga Mbuga	— 6* 32*	Fly returning to mbuga after long interval shows no memory for last place visited. *Nearly 1 mile apart.
93 ...	ii-iii iii v	Transition Mbuga Mbuga	— 20* 1*	Fly possibly passing quickly from stage iii to v in 1 day owing to mbuga physical conditions; also visiting mbuga when replete. *A mile or more apart.

The remaining cases are not sufficiently interesting to give in detail.

It will be seen that there is a certain amount of evidence that fly knows its way about the bush, and that there is considerable traffic from one type to another at

quite short intervals. There is also a suggestion that hungrier flies from "miombo" proceed to "mbugas," and that they remain there for a short time if they do not meet with food.

From examination of these and other results not detailed here it seems possible that the "hunger cycle" may perhaps average from 4 to 8 days, but this is not to be taken as any more than a very tentative suggestion.

There is just one more point arising from these experiments which seems worth mentioning. Of the repleter flies (stages i to iii) taken in "mbuga" and "miombo" respectively, stage i was relatively more numerous in "mbuga" than in "miombo." The stages of the original markings were not fully differentiated until 11th July. From this date onwards the following statistics were obtained:—

A. "Miombo."

Flies marked in stages ii-iii ...	...	...	...	...	469
Flies marked in stage i ...	...	...	...	...	28
Ratio ...	...	...	...	...	1 : 16.75.

B. "Mbuga."

Flies marked in stages ii-iii ...	...	...	...	...	98
Flies marked in stage i ...	...	...	...	...	15
Ratio ...	...	...	...	...	1 : 6.5.

That is to say, of the *repleter flies*, which would be expected to be concerning themselves with the functions of digestion rather than the problem of the next meal, those which had *just* fed were relatively common in the "mbuga"; those which were slightly more advanced were commoner relatively in the "miombo."

If the "mbuga" contains hungrier flies simply because the physical conditions there are such as to hasten the processes of digestion, then the effect on flies in stage i should be as marked, it seems, as it is on stages ii and iii. But if we suppose that flies in stage i, after a stay of perhaps up to a day in the "mbuga," then make their way back to "miombo," the observation is satisfactorily explained in a way which seems to support the feeding-ground concept.

Examination of the hunger curves for the fly-rounds shows a similar condition, but the numbers of stage i flies are small.

C. Mr. Burt's and my Recaptures of his Marked Flies.

At the time when marking of flies was being carried out as described, Mr. Burt was also carrying on daily markings of flies in situations representing respectively male area, female centre, and transitional conditions, about his ecological stations. The disposition of these stations is shown on the map. The female centre station is at the water-holes in the "mbuga" of Wa'amachthla; the transition station a little further up and to one side of the "mbuga"; and the male area station in the *Berlinia-Brachystegia* wooding up above on the south-west slope of Saane hill. The stations are separated from the path used in my marking experiments by about a mile, the *Berlinia-Brachystegia* station being the farthest away.

The intervening country consists largely of *Berlinia-Brachystegia* wooding on Ebaagwute hill. Mr. Burt's stations are separated by some rather dense thicket from the female centres of the Sambala River to the west, and by extensive thicket from the small female centres of the "mbuga" round to the south. It therefore happens that the path used in my marking experiments passed through the only other accessible "centres" in the neighbourhood, except a small one just west of the Ebaagwute road.

Of Mr. Burt's recaptures, during the first two months, June and July, of flies marked by him, the individuals marked in the female centre and retaken in the male

area were several times more numerous, relative to the numbers originally marked, than were those marked in the male area and retaken in the female centre.

These facts suggest the following possible explanations:—

(i) That flies were spending most of their time in the male area and only rarely visiting the female centre ; or (ii) that *some* of the flies residing in Mr. Burt's male area were in the habit of visiting feeding-grounds elsewhere, while other flies from his male area used his Wa'amachthla centre as their feeding-ground ; or, again, (iii) that a combination of these possibilities was responsible. Up to the present no other possibilities have occurred to me.

With regard to possibility (ii), some light appears to be thrown by my recaptures of the flies in the course of the marking experiments. The results of Mr. Burt's and my recaptures of his flies during June and July are given below:—

1. Marked by Mr. Burt—						
Male area station	...	...	...	...	...	1,500
Female centre station	...	...	...	...	...	491
2. Recaptured by Mr. Burt—						
Male area to female centre	...	...	...	...	...	14
Female centre to male area	...	...	...	...	...	14
3. Recaptured by me in marking experiments along the path only—						
Male area flies	...	...	...	...	...	42
Female centre flies	...	...	...	...	...	3

That is, Mr. Burt recaptures 3 times as many of his female centre flies in the male area as he does of his male area flies in the female centre, relative to the numbers marked. On the other hand, I recapture about 4 times as many of his male area flies as I do of his female centre flies, again relative to the numbers marked.

This result seems to support possibility (ii), above, and to give general support to the feeding-ground concept. It does not, of course, rule out possibility (i).

XVI. Other Lines of Evidence bearing on the Feeding-ground Concept.

There remain two important points which may fairly be taken as evidence in favour of the feeding-ground concept.

A. *Considerations on the Apparent Relative Diminution of Fly in Berlinia-Brachystegia during the Mid Dry Season.*

This has already been described on pp. 504–506 and referred to again on p. 512. The essential fact is that, in Sambala, during the later part of the dry season, the number of flies taken in male areas relative to the number taken elsewhere is lower than at other times of year.

For various reasons it is believed that this does not merely represent an increase of activity in female centres with a corresponding diminution of activity in male areas. It seems unlikely that the major changes in physical conditions characteristic of the start of the mid dry season could bring about diametrically opposite reactions on the part of fly in "mbuga" and *Berlinia-Brachystegia* respectively.

There appear to be three possibilities to account for the fly behaviour at this time ; these are : (i) That fly is showing symptoms of incipient concentration-formation of the type described by Shircore, Jack and Swynnerton, because the conditions are now perhaps more severe in the leafless *Berlinia-Brachystegia* than they are in moister valleys and transition zones ; (ii) that fly is spending more of its time outside the *Berlinia-Brachystegia* now that the *general* conditions are hastening the onset of hunger and driving it out more frequently to search for food ; and (iii) that fly perhaps responds first to the second set of factors, and afterwards to the first.

With possibility (iii) we are not at the moment concerned.

As to possibility (i), if the apparent relative diminution of fly in male areas were due to the onset of severer conditions there than elsewhere at this time of year, then such flies as remained in the male areas should show the effect in their external condition, and should be at least as attenuated as flies elsewhere. But as stated on p. 512, it is evident from the graphs of hunger in flies that this is not the case, at least at the commencement of the period of apparent relative diminution. Flies in *Berlinia-Brachystegia*, although they do become hungrier than before, are still in better condition than flies in the female centres and other situations outside them.

It might be argued that they have migrated to *Acacia rooseae* or thicket or other country not tapped by fly-rounds, and this possibility has to be admitted. On the other hand, an examination of the map shows no very obvious place to which fly could have gone which is not covered by one of the fly-rounds. North from Saane hill the *Berlinia-Brachystegia* reaches up to the Mangati Plains, and the only places of refuge seem to be the rather unlikely thickets of the Hara valley to the east, or the Sambala River to the west.

On the whole, therefore, it seems that possibility (ii) is more probable than possibility (i), at any rate during the first part of the period, and that fly is not really leaving the male areas, but only visiting the female centres more frequently than before owing to hunger engendered by the severer conditions generally.

B. Considerations on the Distribution of Game in Female Centres and Male Areas.

Apart from the empirical considerations that female centres, including as they do water-holes and other apparently biotically comparable situations, seem to have more than an accidental association with game, the frequency of game passage through them has definite bearing on the feeding-ground idea.

Female centres are relatively confined in area, so that if fly drifts haphazard into them it should quickly drift out again into the *Berlinia-Brachystegia*, since it does not appreciably penetrate the thicket. The apparent dense concentration of flies in some female centres (for example, at water-holes) seems in any case to argue against the idea that they are there for no particular purpose.

If, however, we suppose that flies drift into female centres accidentally, and once there are in some way inhibited from getting out again (which seems unlikely), then possibly the physical conditions obtaining might have time to show their effect in raising the hunger of the flies in female centres above that of flies in the male areas.

But during the leafless season physical conditions differ very slightly as between the average glade-like female centre and the adjacent male area; whereas the passage of the fly's hosts through confined and easily recognisable portions of the female centres is during most of the year beyond comparison more regular than in similar-sized portions of the relatively huge, featureless male areas. It seems a strain on the probabilities to suppose that this regular game traffic through female centres can be more than counterbalanced by relatively small differences in physical conditions such as have so far been apparent as between Mr. Burt's instrumental readings in his female centre and male area. *Mr. Burt's readings show far less difference between these types than has been shown by the major changes in physical condition from the cold spell to the mid dry season*; and yet the fly in the *Berlinia-Brachystegia*, as is evident from the graphs, did not become nearly so hungry after the end of the cold spell as the "mbuga" fly was in July.

Thus we seem led to reject the purely physical explanation of the greater hunger of female centre flies, although the difference in physical conditions between the two types no doubt plays some part.

XVII. Summary of Evidence for the Feeding-ground Concept.

At this stage it seems desirable to collect and summarise the evidence scattered through the foregoing sections, starting from the position defined under "Further Considerations on the Feeding-Ground Concept," on p. 514.

The alternative possibilities to be distinguished are : (i) That fly becomes hungry in female centres because of the relatively severe conditions obtaining there, or because game is scarcer there than elsewhere ; (ii) that fly appears in female centres because it is feeling the onset of hunger elsewhere.

The lines of evidence are :—

1. The catching-out experiments indicated, so far as they went, that flies really did stream more or less steadily into female centres, whereas a similar movement was not observed in male areas.
2. Direct observations on marked flies failed to afford a definite conclusion because the figures were too small to be considered proof. Some suggestive cases of flies with known histories were collected in the course of the work.
3. The fact that stage i flies (showing red or black blood) were more numerous in female centres than in male areas, relative to the other repleter stages (ii and iii), suggests that fly feeds in female centres and digests its meal in male areas.
4. The fact that, when the apparent relative diminution of fly in *Berlinia-Brachystegia* is in progress, fly in that type is still less hungry than outside it, suggests that a real evacuation is not occurring, and therefore that fly is visiting its feeding-grounds more frequently now that the conditions are more severe.
5. Considerations on game in female centres and male areas, coupled with a comparison of changes in physical conditions in place and time, seem strongly against a physical explanation of differentially greater hunger in female centres.
6. The scarcity of young (unfed) flies in male areas, where breeding is known to occur, and their relative abundance in female centres, where from empirical considerations it is unlikely that successful breeding is at all considerable, argue that young flies leave the male areas for the female centres in search of their first meal.
7. An analysis of Mr. Burt's and my recaptures of his marked flies seems to give evidence in favour of the feeding-ground concept.

While, therefore, the matter must still be considered open, there is a certain amount of evidence in favour of the feeding-ground concept, and against the alternative purely physical explanation of the observations.

The conclusion that the male area is the true *home* of the fly derives some general support from the fact that it is *Berlinia-Brachystegia* and *Copaifeira mopani* wooding that constitute the two alternate common factors of *Glossina morsitans* distribution practically throughout South-East and Tropical East Africa.

XVIII. Fly Numbers and the Movements of Game.

At the start of the investigation it was hoped that a study of the game movements by the method outlined in Section VII would lead to the establishment of a direct correlation between the numbers of fly and the numbers of game obtained from the fly-rounds. No such direct correlation is evident from the graphs, although game numbers of reasonable accuracy have been plotted against fly numbers, total female percentage, and female percentage of old flies alone.

Plotting the numbers of fly and of game from single female centres, and plotting against each other numbers from adjacent female centres, gave similarly disappointing results.

The explanation seems to be that, in the Sambala area, fly responds to physical factors so markedly as to mask any effect that may be produced by the movement of game.

Thus from July to August 1929 fly in all the vegetation communities became appreciably hungrier in correlation with rising evaporation-rate and the associated changes in physical conditions, although game was actually becoming commoner during that time, and had in fact been increasing since early in June. There was also a rise in the female percentage, both in the female centres and through the country generally.

Again, in the Samba country to the south, in 1928, the female proportion for the area rose steadily through the dry season from a very low figure at the end of the rains to a sustained level of about 45 per cent. in August and September. At the same time the records of spoor from fly-rounds carried on there at that time seemed to show no appreciable change in the game population. This period was characterised by a considerable increase in fly.

Examination of the fly and game numbers from single female centres often seems to show a direct correlation between the advent of game, a rise in fly numbers, and a rise in the female percentage. But comparison with other centres during the same period shows that these changes in fly numbers are characteristic of most if not all female centres at that season apparently irrespective of the numbers of game present. The apparent correlation is often due to the fact that, at the time of the year when physical conditions seem to re-establish female centres after the rains and the cold spell, game happens to be entering the area in search of water or grazing.

The lack of a real direct correlation is evident from a comparison of the female centres on graphs of the type used in this paper to illustrate the distribution of fly on the Lankasese round. If curves from game numbers in the various transects are superimposed on a graph of this kind it becomes obvious that the numbers of game in the several female centres do not directly determine the temporary, relative importance, as judged by apparent fly numbers and proportions, of those female centres to each other or to the round as a whole.

But, although the data have not so far afforded undeniable indication of a direct relation between fly and game, there is a suspicion that a carefully thought-out, properly controlled experiment might give a more interesting result, and that an increase in game traffic through a female centre may possibly be able differentially to raise the total numbers and the female percentage of fly in that centre.

On the whole, therefore, it is believed that, at any rate in the special conditions represented at Sambala, game is ordinarily more than sufficiently numerous to feed the fly, and that an increase in the numbers of the game is not capable of showing any direct effect on the general fly population, because any effect there may be is masked by the influence of the physical conditions.

XIX. General Interpretation of Fly-round Results.

No data have been obtained bearing on the seasonal variations in the death-rate of flies, and consequently it is very difficult to reach any definite conclusions on actual fly density.

As, however, flies seem to become hungrier with a rise in evaporation-rate and its associated conditions, and as hungrier flies are probably more likely to attack man, it seems reasonable to suppose that rising evaporation-rate and temperature may result in an apparent increase in fly, unless the death-rate is temporarily increased or the emergence-rate checked.

The apparent diminution of fly in the late dry season may for the same reasons represent a real decrease, due either to increased death-rate or to cessation of emergence.

The rise in fly numbers at the start of the short rains may represent a real increase, since the evaporation-rate and temperature presumably fall at this time; but if so, it is difficult to understand why, if the percentage of soft flies has any meaning, this does not show a rise instead of a fall. The rise in fly at the start of the short rains is especially difficult to understand, since the onset of the long rains is characterised by a fall in fly numbers. On the other hand, both periods show a fall in percentages of females and young flies.

On the whole, it is very apparent that far more ecological and laboratory data are needed before one can base reliable conclusions on these results.

So far, there have been considered only female centres, male areas, and their transitions. As stated in Section XI, at least two other types of fly community seem to exist.

1. "Spread Centres." This name was given to larger areas with apparently dense fly and high female percentage. Such areas may include local aggregations of fly of the female centre type.

It is considered that such communities, which may occupy extensive areas, represent diffuse feeding-grounds not essentially different in function from true female centres. The apparent density of fly in a "spread centre" is believed to depend on the size of the area available for its occupation, its proximity to the nearest male area, the linear margin of contact between them, and the density of the fly in the male area itself.

Thus, if a number of male areas are pouring hungry flies into a confined situation more or less surrounded by them, the density of fly in that confined situation will be high, and the situation will have the characteristics of a true female centre. But if a male area is pouring flies into a piece of country as large as or larger than itself, and in contact with it on a broad front, then the result will be a "spread centre" with or without local aggregations of denser fly.

These considerations seem borne out by examination of a map of the whole area.

2. Scarce-fly Areas. Flies found about the external or internal limits of the range of the general fly population are supposed to represent either extreme "spread centres" or scattered individuals which have for some reason (*e.g.*, carriage on game) strayed outside the temporary or possible boundaries of the fly belt.

The percentage of females among these flies is high and they are therefore presumably hungry. This is understandable in fly living about at the limits of the range of the species.

3. Finally, in certain situations where favourable male areas are absent, there is no empirical reason why fly should not spend all its time in its feeding-grounds, if these happen to provide the requisite conditions. Something of this sort may possibly account for the situation observed in the Samba area, where fly seems to be practically absent from the *Berlinia-Brachystegia*, and to exhibit an undifferentiated distribution along narrow "mbugas" dominated by *Acacia roovumae*.

XX. Summary.

1. Fly rounds and reconnaissances about Sambala have indicated the following types of fly community: (a) Compact "female centres" characterised by frequent passage of game, and showing high apparent female percentage and often apparent concentration of fly; (b) "spread centres" over larger areas believed to be comparable

in function to true, compact "female centres"; (c) "male areas" spread over large areas of *Berlinia-Brachystegia* and sometimes other kinds of wooding, where the apparent female percentage is low; (d) areas where fly is scarce.

2. Investigation of these phenomena by field experiments and other methods has led to the conclusion that the "female centres" and "spread centres" are most probably feeding-grounds of fly, and that the "male areas" are its home.

3. It is difficult to draw reliable conclusions from fly-rounds on the apparent variations of fly numbers in time, in relation either to season or to movements of game.

Literature cited.

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ON SANDFLIES FROM PERSIA AND PALESTINE.*

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(PLATES XXIII & XXIV.)

The material dealt with in this paper was collected from 27th May to 3rd July 1929 on a trip through Persia. The route followed was the usual motor route from Khanikin *via* Kerind, Kermanshah, Hamadan to Teheran, and from Teheran *via* Kazvind to Resht and Pahlevi (Enzeli) on the Caspian. The return journey was made along the same route. Collections were made at the above towns and as far as possible at the resting places between them. Attention was paid particularly to Teheran, a notorious endemic centre of oriental sore, where collection proceeded for 15 days, Resht (10 days), and Hamadan, where the discovery of *Phlebotomus chinensis* raised the suspicion of the presence of kala-azar and led to an intensive study of the sandfly population during the seven days at our disposal.

There are no accurate data as to the distribution of leishmaniasis in the areas examined *en route*. Cutaneous leishmaniasis is common in man and dog in Khanikin near the Mesopotamian border. In Kermanshah, about 150 miles from Khanikin, local practitioners state that cases occur only in people who have visited Baghdad. In Hamadan very few indigenous cases of oriental sore have been observed. In Kazvind and Teheran (about 190 miles from Hamadan) oriental sore is common in man and dog.† In Resht, near the Caspian Sea, a few indigenous cases of oriental sore have been observed in man.

Human visceral leishmaniasis has never been recorded from Persia, but we think the introduction of modern methods of diagnosis will reveal the existence of kala-azar at least in Northern Persia in the neighbourhood of Transcaspia and Caucasia, which are endemic centres of both visceral and cutaneous leishmaniasis.

So far as the sandfly population is concerned, the area examined may be divided into three parts.

1. The district round Resht and Pahlevi, where three species of sandflies occur, *Phlebotomus papatasi*, *P. perniciosus* var. *tobbi*, nov., and *P. kandelaki*, which is rare. This district is adjacent to the southern border of the Caspian and is by far the most humid part of Persia; the rainfall is said to be five times that of the country between Teheran and Kazvind, from which it is separated by a range of mountains.

2. Teheran and Kazvind. This district is the heaviest centre of cutaneous leishmaniasis, human and canine, in Persia. In this respect it may be compared with Baghdad, for scarcely a human being escapes the disease. There are three common species of sandflies, *P. papatasi*, *P. caucasicus*, and, in much smaller numbers, *P. sergenti*. *P. chinensis* occurs rarely.

* This investigation was carried out with the aid of a grant from Dr. Julius Moses, Mannheim.

† Oriental sore is probably of comparatively recent origin in Teheran. It was not common in 1810–1816 when the novelist Morier was in Teheran. Morier apparently shared a contemporary popular view that the typical scars of healed sores on the face were a sign of previous residence in Baghdad. In the course of his famous novel, "Haji Baba of Ispahan," Morier describes a typical case of oriental sore on the face acquired in Baghdad, its spontaneous healing in eighteen months, and the typical scar. Although the novelist frequently refers to medical practice in Teheran he does not mention oriental sore except as a disease peculiar to Baghdad. About the middle of the nineteenth century oriental sore was very common in man and dog in Teheran and very few people escaped the disease. (Schlimmer 1874.)

3. The district including Hamadan and Kermanshah. The sandfly fauna of this district is much richer than that of the other two. There are three common species of the *major* group, *P. wenyoni*, sp. n., *P. kandelaki*, and *P. chinensis*. In addition *P. caucasicus* and *P. papatasii* are common and *P. sergenti* is rare.

We were surprised at the rarity of members of the *minutus* group throughout the whole region examined; only one single specimen, a female of *P. palestinensis*, was caught at Abu Germ, between Teheran and Hamadan.

It will be observed that *P. papatasii* is ubiquitous and is found in all the ranges of topographical and climatic conditions in the area examined. It has the widest distribution of all known species of *Phlebotomus*, and no other sandfly is so adaptable to extremes of climatic conditions; it is common in dry and almost desert regions like Aleppo and in temperate regions such as Southern France. *P. caucasicus* is common throughout the whole of the region examined outside the moist belt bordering the Caspian. *P. kandelaki*, *P. wenyoni*, and *P. chinensis*, appear to be restricted to the highlands (5,000 feet and more above sea-level) where the summer is comparatively mild.

In forming even a rough estimate of the relative frequency of species in a given locality the time of collection must be considered. The worker may get an entirely erroneous idea of the prevalence of a species if he restricts his collecting activity to a given period of the day. Thus in Resht sandflies caught in the early morning will be mainly *P. papatasii*. At dusk, up to about 9 p.m., *P. perniciosus* var. *tobbi* will be found to be more numerous than *P. papatasii*. *P. perniciosus* var. *tobbi* comes out in large numbers in the early evening and by about 9 p.m. are fully gorged and disappear into holes in walls or any other convenient hiding places. *P. papatasii* comes out later, and at 11 p.m. most of the specimens caught will be *P. papatasii*. *P. wenyoni*, which is a fairly common species in Hamadan, would have been overlooked entirely if collecting had not been carried out in the early hours of the morning. This species is found between midnight and dawn. *P. chinensis* is rarely found during the day and, like *P. wenyoni* which it resembles in external characters, is found mainly after midnight. In Teheran we carefully examined a house in which there were two cases of oriental sore without finding any sandfly between 7 and 9 p.m. On leaving, about 11.30 p.m., we found 9 fully gorged females of *P. sergenti* sitting in cracks in the wall of the courtyard. On dissection they were found to contain freshly ingested mammalian blood, probably human. *P. caucasicus* is found at all hours of the day in Teheran. In nature this species feeds as readily by day as by night, and is responsible for disturbing the siestas of Europeans in Teheran.

Macroscopic external characters are not of great value in the diagnosis of sandflies, but the following facts may be noted. The species of the *major* group, which includes *P. major*, *P. wenyoni*, *P. kandelaki*, and (sensu lato) *P. chinensis*, have relatively much longer legs than *P. papatasii*, *P. caucasicus* and *P. sergenti*, and though they cannot be distinguished from each other, they can as a group be readily distinguished from the other species *in vivo*. The males of *P. caucasicus* and *P. sergenti* have much shorter external genitalia than the other species. *In vivo* the males of these two species can usually be distinguished at a glance; the body of *P. sergenti* is straight, while that of *P. caucasicus* is bent upwards posteriorly. *P. caucasicus* moves its body up and down and from side to side, while the body of *P. sergenti* is kept rigid. *P. caucasicus* is the least sensitive of all known sandflies with regard to light; it is found not only indoors but outside on walls where there is comparatively little shade. Some recently gorged specimens were caught in open-air cafés at about 3 p.m. The members of the *major* group are found mainly in moist dark cellars and bathrooms. *P. sergenti* is very photophobic and creeps into any suitable dark hole available shortly after feeding; if not carefully sought it may be overlooked even in houses where it is relatively common.

Until 1926 the diagnosis of sandflies was based on external characters. Males could be diagnosed by their external genitalia, but females were difficult or impossible to determine. The introduction of the spermathecae, pharynx and buccal cavity as systematic characters made the diagnosis of females possible. These characters are not only convenient but they also form the basis of a natural classification, for groups of closely related sandflies show graded modifications. The importance of distinguishing closely related forms cannot be over-estimated, particularly at the present time when experimental investigations of sandflies as vectors of disease are in their preliminary stage.

In a previous paper the view was expressed that sandflies should be removed from the PSYCHODIDAE and should form a new family PHLEBOTOMIDAE. The habit of haematophagy and the changes in the mouth-parts which this involves appear to be sufficient grounds for the formation of a new family.

Records of the Species.

***Phlebotomus papatasi*, Scop.**

Distribution and material examined: Teheran, 93 ♀♀, 33 ♂♂; Abu Germ, 10 ♀♀, 2 ♂♂; Kerind, 16 ♀♀, 5 ♂♂; Aabanshah, 14 ♀♀, 7 ♂♂; Menjil, 20 ♀♀, 5 ♂♂; Rutbah, 2 ♀♀; Kazvind, 5 ♀♀, 4 ♂♂; Hamadan, 119 ♀♀, 44 ♂♂; Resht, 63 ♀♀, 79 ♂♂; Kermanshah, 59 ♀♀, 21 ♂♂.

***Phlebotomus sergenti*, Parrot 1917.**

P. sergenti var. *alexandri*, Sinton 1928, *pro parte*.

The specimens from Persia are similar in every detail to those from Mesopotamia and Syria. Outside Teheran this species is relatively rare in N.W. Persia.

Distribution and material examined: Teheran, 26 ♀♀, 8 ♂♂; Kazvind, 1 ♂; Assadabad, 1 ♀.

***Phlebotomus caucasicus*, Marzinovski 1917.**

P. sergenti, Newstead 1920.

P. li, Popov 1925.

P. sergenti var. *lii*, Parrot 1928.

The synonymy of this species has been in a state of confusion. Marzinovski made the species on the characters of the external male genitalia. Popov (1925) came to the conclusion that *P. sergenti* and *P. caucasicus* are different species on account of minor differences in the antennal measurements and in the wing venation. Neither of these characters is in itself of specific value; the wing venation particularly is subject to wide variations in the same species. Popov described a new species, *P. li*, on the grounds of the broad brush of hairs on the proximal segment of the upper clasper in the male. Newstead (1920) described the same species from Mshed in N.E. Persia and considered it to be *P. sergenti*, Parrot. Newstead's drawing leaves no doubt as to the identity of his specimens with *P. caucasicus*.

In a recent letter Prof. Marzinovski wrote: "Dr. Popov in 1925 erroneously attributed the fine brush of hairs to my *P. caucasicus* . . . in his review he called *P. sergenti* by the name *P. caucasicus* and created a new species *P. li* possessing a large brush on the upper claspers. I did not notice this error at the time, but now I see from my article that *P. caucasicus* possessed a large brush. *P. li* is therefore a synonym of *P. caucasicus*."

The *sergenti* group therefore contains two species and two varieties. *P. sergenti*, Parrot, in Europe, North Africa, Asia Minor, Mesopotamia, and Persia; *P. caucasicus*

in North Persia (Meshed), Caucasus, Turkestan, Afghanistan, and Bokhara; *P. sergenti* var. *mongolensis* in China; and *P. sergenti* var. *alexandri* in India, Mesopotamia, and Tadzhikistan.

The male of *P. caucasicus* has been described and figured by Marzinovski, Popov, Newstead, and Parrot.

Size: 1.5 mm. to 3 mm.

Palp formula: 1, 4, 2, 3, 5 or 1, (4, 2) 3, 5. *Antennae*: Segment 3 $\geq 4+5$. *Wing index*: $\alpha/\beta=1.3-2.3$. This measurement is quite sufficient to show that this character is of no specific value. *Genitalia*: Popov's figure of the brush of hairs on the proximal segment of the superior clasper is rather inaccurate, for it gives the impression that the hairs rise directly from the surface of the clasper. Actually they rise from an elongated club-shaped chitinous process. In *P. sergenti* the hairs rise only from the tip of the process, in *P. caucasicus* from the tip and a large part of the ventral surface (Plate XXIII, figs. 1, 2). *Pharynx*: The armature is similar to that of the male of *P. sergenti*. The median teeth are much less developed than in the female and appear as a network of lines. The lateral teeth extend further anteriorly than the median ones.

♀. Size: 1.6 to 3.3 mm.

Palp formula: 1, 4, 2, 3, 5 or 1, (4, 2) 3, 5 or 1, 2, 4, 3, 5. *Antennae*: Segment 3 $4+5$. *Wing index*: $\alpha/\beta=1.25-1.8$. *Pharynx* (Plate XXIV, fig. 1; text fig. 1, c):

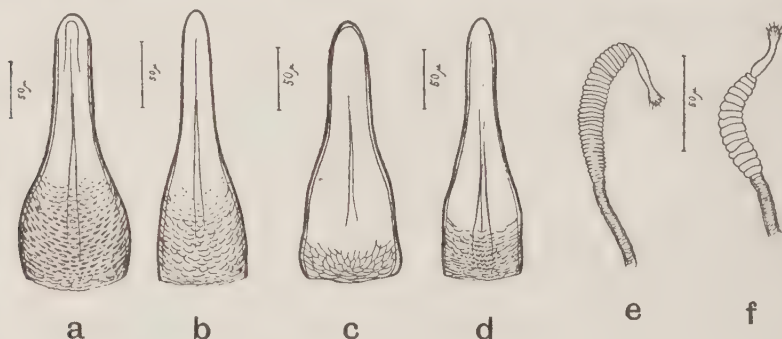


Fig. 1. Pharynx of: (a) *Phlebotomus wenyoni*, ♀; (b) *P. wenyoni*, ♂; (c) *P. caucasicus*, ♀; (d) *P. kandelaki*, ♀. Spermathecae of: (e) *P. kandelaki*; (f) *P. perniciosus* var. *tobbi*.

The general arrangement of the teeth is similar to that of *P. sergenti*, but they do not reach so far anteriorly as in the latter species and are less strongly developed. The pharyngeal armature of *P. sergenti* var. *mongolensis* is intermediate in type between that of *P. sergenti* and *P. caucasicus*. The teeth in the pharynx of *P. caucasicus* are rather coarse and blunt; the axis of the middle teeth is longitudinal, that of the side teeth is oblique laterally. In *P. sergenti* all the teeth have their axis longitudinal. *Spermathecae* indistinguishable from those of *P. sergenti*. They consist of 4 or 5 narrow segments and one wider, rounded, apical segment.

Distribution and material examined: Teheran, 149 ♀♀, 99 ♂♂; Abu Germ, 101 ♀♀, 50 ♂♂; Kerind, 11 ♀♀, 3 ♂♂; Aabanshah, 1 ♀; Assadabad, 4 ♀♀, 1 ♂; Hamadan, 103 ♀♀, 88 ♂♂; Kermanshah, 7 ♀♀, 26 ♂♂; Kazvind, 4 ♀♀, 1 ♂.

Both the male and female of *P. caucasicus* show large variations in size. In some districts in Teheran only large forms are found, in others large and dwarf forms occur together. It remains to be determined whether there are two distinct races of *P.*

caucasicus or whether the differences in size depend on the amount of nutrition available during the larval stage. Other species also have dwarf forms, e.g., *P. sergenti*, *P. papatasi*, and *P. chinensis*.

Sinton recorded *P. sergenti* var., Newstead 1920, from India and named it *P. sergenti* var. *alexandri*. He included all the Mesopotamian forms in this variety. The sandflies common in Baghdad and Mosul are clearly identical with *P. sergenti*, Parrot.

Perfiliev (1929) gave a detailed description of the male of *P. sergenti* var. *alexandri* from Tadzhikistan. He considers this variety to be identical with *P. sergenti* var. *alexandri* from Mesopotamia. Dr. Perfiliev kindly sent us one of his specimens, which can be clearly distinguished from *P. sergenti* by the character of the distal segment of the brush on the superior clasper, as well as by the length of the third antennal segment.

Major Sinton kindly sent us one male and one female of *P. sergenti* var. *alexandri* from India. Both are readily distinguishable from *P. sergenti*. The female differs in the spermathecae, which have eight segments as against three to five in *P. sergenti*, in the antennae and in the pharynx. The teeth are a little more oblique and extend slightly less forward than in the pharynx of *P. sergenti*.

Newstead's variety is therefore valid and not as we previously thought a synonym of *P. sergenti*, Parrot. Although *P. sergenti* var. *alexandri* was originally described from Mesopotamia, it is extremely rare in that country and we did not encounter a single specimen among 250 males caught in Baghdad and Mosul.

The examination of sandflies of this group in minute detail is of more than academic and systematic importance, for species such as *P. caucasicus* and *P. sergenti*, which are so closely related morphologically as to have been repeatedly confused by systematists, show even in districts where they co-exist large differences in bionomics. The distribution of *P. sergenti* corresponds very closely with that of oriental sore in Mesopotamia and Persia, while that of *P. caucasicus* appears to be in no way related to the above disease.

***Phlebotomus chinensis*, Newstead.**

P. major var. *chinensis*, Newstead 1916.

P. major var. *longiductus*, Parrot 1928.

This species has been fully described in a previous paper. *P. chinensis* more than any other known sandfly tends to form local races. These differ mainly in the form of the intromittent organ and the length of the genital filaments of the male, but the females from various localities are practically indistinguishable (except the North Palestinian form). Males of *P. chinensis* from Aleppo can readily be distinguished from the Chinese form. The Persian form is very similar to that from Aleppo, but is more lightly pigmented. The male of *P. chinensis* from North Palestine can readily be distinguished from the Chinese and Syrian forms. The genital filaments of the males from Aleppo and Persia are very long, those of the specimens from China are relatively short, and in the forms from Rosh Pinah they are intermediate between the other two. It remains to be determined experimentally whether the various local forms show biological differences of any significance for the transmission of disease.

When *P. chinensis* was discovered in Syria (1928) it was realised that this sandfly had a very wide distribution, and its presence in other parts of the Mediterranean basin was predicted. This prediction has recently been justified, for Nitzulescu (1929) has recorded two forms of *P. chinensis*, one from Rumania and another from

Jugoslavia.* In Italy we found in 1929 a few females of a sandfly which has several characters of the *chinensis* group. This species is dealt with more fully in another paper.

The following local forms or races of *P. chinensis* are known :—

1. *P. chinensis* from China. Characterised by a flat tubercle on the penis and rather short genital filaments.

2(a). *P. chinensis* from Persia. Faint pigmentation. Broad penis with a very pronounced tubercle. The genital filaments are very long. Feeble development of the teeth in the male pharynx. Prof. Marzinovski sent us specimens of this form from

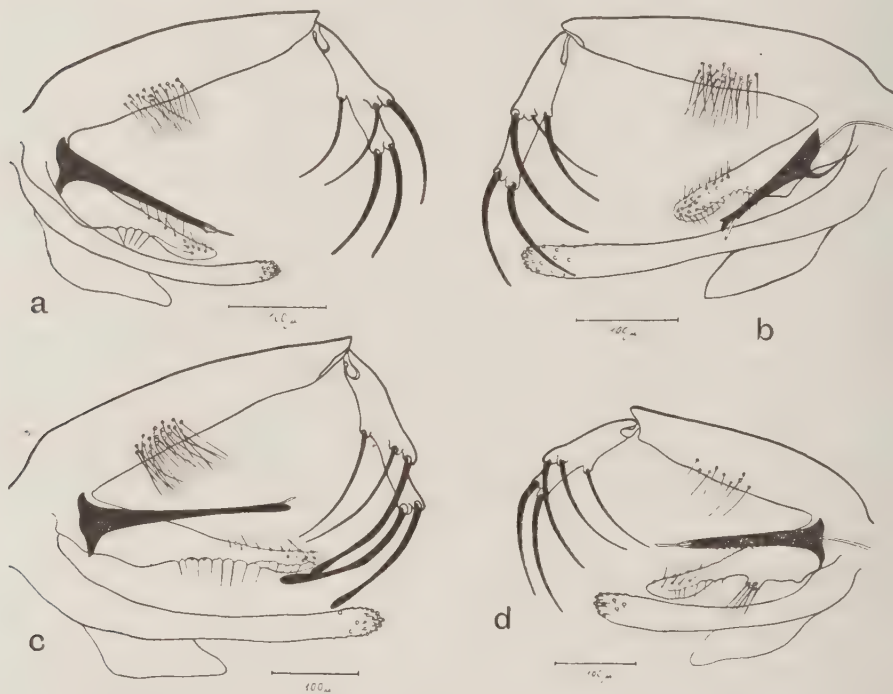


Fig. 2. Male genitalia of : a, *Phlebotomus chinensis*, from Palestine ; b, *P. perniciosus* var. *tobbi* ; c, *P. wenyoni* ; d, *P. kandelaki*.

Tiflis, and Dr. Perfiliev from Turkestan. Parrot's specimens from Bokhara, upon which he described his var. *longiductus*, seem to belong to this form.

2(b). *P. chinensis* from Syria. Penis as in the Persian form. Strong pigmentation. Teeth in pharynx slightly more developed than in the Persian form.

3. *P. chinensis* from North Palestine. This form is characterised by its small size, which was constant in about 60 specimens examined. The wing index is always less than 2. Genital filaments of median length. The tubercle on the penis is more prominent than in other forms.

4. Rumanian form similar to the Syrian form.

* An examination of material in the collections of the British Museum and the London School of Tropical Medicine showed that this species is common in Macedonia.

5. Yugoslavian form similar to the Palestinian form, but larger.

Distribution and material examined: Hamadan, 24 ♀♀, 31 ♂♂; Teheran, 1 ♂; Kerind, 2 ♀♀.

Description of the male of P. chinensis from Rosh Pinah in North Palestine.

Size, 1.8–2.1 mm.

Palp formula: 1, 4, 2, 3, 5 or 1, 4, (2, 3), 5. *Antennae*: Segment 3 $\geq 4+5$. *Wing index*: $a/\beta=1.5-1.8$. *Genitalia*: The only constant difference from other forms is found in the penis. The shaft of the penis narrows behind the well developed, sharply angular tubercle. The intermediate appendage is similar to that of other forms of *P. chinensis*. In general the form of the intermediate appendage of *P. chinensis* is similar to that of *P. major*, but the neck is relatively shorter (fig. 2, a). The female has been described in a previous paper (1928).

Material examined: Rosh Pinah, 34 ♀♀, 16 ♂♂.

***Phlebotomus wenyoni*, Adler & Theod., sp. n.**

♀. *Size*: 2.8–3 mm.

Palp formula: 1, 4, (2, 3), 5. *Wing index*: $a/\beta=1.5-1.9$. *Antennae*: Segment 3 $> 4+5$. *Pharynx* (Plate XXIV, fig. 2, and text-fig. 1, a): The pharynx is very characteristic and offers a ready means of diagnosis. Viewed dorsally it is seen to be covered in the whole of its broad part with teeth arranged in parallel and slightly curved rows. The teeth are much larger than those of *P. major* and reach almost half-way up the pharynx. *Spermathecae* of the *major* type, with about 15 segments, a long neck and rather narrow ducts.

♂. *Size*: 3–3.3 mm.

Palp formula: 1, 4, 2, 3, 5. *Antennae*: Segment 3 $> 4+5$. *Wing index*: $a/\beta=1.15-2.1$. *Pharynx* (fig. 1, b) similar to that of the female but narrower. In optical section the individual teeth appear as irregular short lines. The teeth extend into the upper half of the pharynx.

Genitalia (text-fig. 2, c) of the *major* type. The distal segment of the superior clasper is about half the length of the proximal segment and bears two long curved terminal spines, one very strong and one thinner spine about the junction of the middle and apical third of the segment, and one fine spine in the middle of the segment. The intermediate appendage is long, slender, and club-shaped, and bears many fine hairs. The penis is very similar to that of *P. major*. It is slender and rounded at its slightly thickened extremity. The genital filaments emerge somewhat behind the extremity. The inferior clasper is as long as the superior one.

The general arrangement of the teeth in the pharynx, the spermathecae and external male genitalia place the sandfly in the *major* group. It is however readily distinguished from every other member of this group by the arrangement of the teeth in the pharynx in both sexes.

We dedicate this species to Dr. C. M. Wenyon, F.R.S.

Material examined: Hamadan, 25 ♀♀, 53 ♂♂.

Type specimens in the Department of Parasitology, Microbiological Institute, Hebrew University, Jerusalem.

***Phlebotomus kandelaki*, Schourenkova 1929.**

We found this sandfly in Hamadan in June 1929 and intended to describe it as a new species. In November 1929, Dr. Schourenkova sent us specimens of this species collected in Tiflis in July 1929 and asked us to compare her material with

other closely related sandflies. Dr. Schourenkova has since informed us that she has named and described the species in the Russian Jl. of Trop. Medicine, vii, no. 10, December 1929.

♀. Size: 2.3–2.5 mm.

Palp formula: 1, 4, (2, 3), 5. *Antennae*: Segment $3 \geq 4+5$. *Wing index*: $a/\beta = 1.6-1.8$. *Pharynx* (Plate XXIV, fig. 3; text-fig. 1, d): The general arrangement of the teeth is similar to that of *P. major*. The pharynx of the females of the *major* group have a common pattern of dentition which varies more or less in different species. In optical section the teeth appear as parallel rows of points or short horizontal lines. In *P. kandelaki* the middle teeth are larger and thicker than the lateral ones. *Spermathecae* of the *major* type, consisting of about 30 to 35 segments. The segmentation is fainter than in other species of the *major* group, especially posteriorly; in this they have some resemblance to the spermathecae of *P. chinensis*. The neck bears a rather wide head (text-fig. 1, e).

♂. Size: 2–2.7 mm.

Palp formula: 1, 4, 2, 3, 5 or 1, (4, 2), 3, 5. *Antennae*: Segment $3 \geq 4+5$. *Wing index*: $a/\beta = 1.4-1.7$. *Pharynx* differing from that of *P. major* in that the teeth in optical section appear as irregular ridges, which do not bear the fine points characteristic of the female pharynx. *Genitalia* (text-fig. 2, d) of the *major* type. The distal segment of the superior clasper is distinctly shorter than half the proximal segment. It bears five almost equal spines, of which two are terminal, one is situated at about the middle of the segment, and two near the junction of the third and apical quarters. One of the two latter spines and the one at the middle of the segment are thinner than the others. The intermediate appendage is rather slender and club-shaped and at the beginning of its broad base has a characteristic process bearing six or seven long thick spines. The penis tapers towards the end through which the genital filaments pass, its lower margin being roughly serrated. The inferior clasper is as long as the superior one.

This species is distinguished from other members of the *major* group by the pharynx and the spermathecae in the female and by the pharynx, intermediate appendage and penis in the male.

Material examined: Hamadan, 26 ♀♀, 38 ♂♂; Kermanshah, 19 ♀♀, 3 ♂♂; Resht, 6 ♀♀, 5 ♂♂.

***Phlebotomus perniciosus* var. *tobbi*, Adler & Theod., var. n.**

In Persia and Palestine we found a variety of *P. perniciosus* that shows constant differences from the typical form in the male genitalia. The insects are rather dark coloured.

♀. Size: 2.4–3 mm.

Palp formula: 1, 4, (2, 3), 5 or 1, 4, 2, 3, 5. *Antennae*: Segment $3 \geq 4+5$. *Wing index*: $a/\beta = 1.5-1.85$. *Pharynx* similar to that of *P. perniciosus*. *Spermathecae* of the *major* type, with about 15 well-defined segments and wide ducts (text-fig. 1, f).

♂. Size: 2.5–3 mm.

Palp formula: 1, 4, 2, 3, 5. *Antennae*: Segment $3 > 4+5$. *Wing index*: $a/\beta = 1.33-1.9$. *Pharynx* similar to that of the female. *Genitalia* (text-fig. 2, b) of the *major* type. The distal segment of the superior clasper is about as half as long as the proximal segment. It bears two terminal spines, one finer spine at about the middle of the segment, and slightly distally to it two spines, one thinner and one coarser. The intermediate appendage is rather stout, having a broad club-shaped head with a well-marked short neck and a broad base. The penis has a very broad

base and tapers towards the end, which is bifid, one fork being much broader than the other. In *P. perniciosus* the forks are nearly equal. The inferior clasper is distinctly longer than the superior one.

Var. *tobbi* is distinguished from the typical *P. perniciosus* by a number of minor but constant differences. In the male the shape of the penis is different, and the two middle spines of the distal segment of the superior clasper are situated very close to the proximal one, while in the typical *P. perniciosus* the two middle spines are half-way between the terminal ones and the proximal one.

Material examined: Resht, 41 ♀♀, 53 ♂♂; Rosh Pinah, 42 ♀♀, 52 ♂♂; Ajeleth, 27 ♀♀, 40 ♂♂.

We dedicate this variety to Dr. Agha Khan Tobb, of Resht, through whose kindness we were able to carry out our work in Resht.

Type specimens in the Department of Parasitology, Microbiological Institute, Hebrew University, Jerusalem.

Phlebotomus tiberiadis, sp. n.

Phlebotomus sp., near *clydei*, Adler & Theod. 1929.

In the description of this species we pointed out that a comparison with specimens of *P. clydei* from India might show the two species to be distinct. We have been able to confirm this through the kindness of Major Sinton. The buccal cavity of the male is entirely different in the two species. The species is therefore to be considered as new.

The Breeding of Sandflies en route.

P. papatasi, *P. causicus*, and *P. sergenti* can be bred even on long motor journeys without great difficulty. The sandflies are put into earthenware vessels, which are closed with muslin over which a lid is placed. The lid is kept in place by a piece of string tied round the whole vessel. The latter is then placed in a wooden box filled with moist earth and then covered with a further layer of 3 or 4 centimetres of earth. Narrow vertical channels are made from the surface almost to the floor of the box and the moisture is adjusted by pouring water down the channels. The moisture disseminates uniformly from the bottom of the channels throughout the whole medium.

Another simple method is to wrap the whole vessel containing the sandflies in lint or cottonwool and to keep the lint slightly moist. The vessels are opened from time to time in a small cage, and if the sandflies have laid eggs a mixture of rabbit faeces and earth is added and the vessels are then replaced. Apart from adjusting the moisture the apparatus needs no further attention until brought to the laboratory. Using the above method, sandflies caught in Teheran, Resht, and Baghdad (*P. papatasi*, *P. sergenti*, and *P. causicus*) were bred out in the laboratory in Jerusalem. Three further generations of *P. causicus* were raised in the laboratory.

Infection Experiments.

Although the distribution of *P. causicus* in Persia does not correspond with that of oriental sore, several experiments were carried out to determine the behaviour of *Leishmania tropica* in this sandfly. (It must be pointed out that endemic foci of oriental sore in Persia differ from other localities not only in their sandfly population but also in their meteorological conditions.)

In the laboratory *P. causicus* does not feed as readily as *P. papatasi* on man, animals, or through membranes. This applies to laboratory-bred as well as to caught specimens.

In Teheran 76 ♀♀ of *P. caucasicus*, 45 ♀♀ of *P. papatasii* and 14 ♀♀ of *P. sergenti* were dissected and were not found to contain any natural infection.

Between 11.ix.29 and 19.ix.29 nine specimens of *P. caucasicus* (laboratory-bred) were fed by Hertig's method on cultures of *L. tropica*. Of these, seven fed on a strain of *L. tropica* isolated in Bokhara by Prof. Marzinovski.

Result: Four sandflies dissected from 3 to 6 days after the feed were positive. The infection was in all cases confined to the stomach. Two sandflies fed on a Palestinian strain of *L. tropica*, and one was found positive after one day.

Six specimens of *P. perniciosus* var. *tobbi* (laboratory-bred from females caught at Rosh Pinah) were fed through capillaries on cultures of *L. donovani* isolated from a dog, which had been infected by direct inoculation from a case of infantile kala-azar in Naples.

Result: Three were positive. In one dissected 3 days after the feed the infection was confined to the stomach. In one dissected 5 days after the feed there was a slight infection confined to the top of the cardia. The flagellates were attached to the rhabdiorium. In one dissected after 10 days there was a moderate infection in the cardia and stomach. Flagellates were attached to the rhabdiorium of the cardia.

(One female *P. major* fed on the same strain and dissected 3 days after the feed showed an infection in stomach and cardia.)

Seven females of *P. perniciosus* var. *tobbi* (laboratory-bred) fed on a strain of *L. donovani* isolated from a child in the Hadassah Hospital, Haifa.

Result: Two were positive. In one dissected 7 days after the feed there was a slight infection in the stomach and cardia, and in another dissected after 7 days the infection was confined to the stomach.

We were not very successful in feeding *P. perniciosus* var. *tobbi* through capillaries by Hertig's method. We doubt whether this is due to faulty technique, for we had no difficulty in feeding *P. papatasii* or *P. caucasicus*. *P. papatasii*, in particular, feeds very readily by this method; the liquid enters the food-canal almost instantaneously, and the sandfly gorges itself quickly. In the case of *P. perniciosus* var. *tobbi* the majority of the sandflies did not feed at all, and those that did feed ingested very little fluid. The amount of flagellates ingested by *P. perniciosus* var. *tobbi* in the above experiments gave a nil infection rate in *P. papatasii* fed through membranes on the same strains. These facts suggest that the strains employed are better adapted to *P. perniciosus* var. *tobbi* than to *P. papatasii*. We attach significance to the presence of flagellates in the upper part of the cardia in one sandfly at a time when the stomach contained no flagellates. This phenomenon occurs in slight infections of *P. papatasii* with *L. tropica*, and we have never observed it in the case of *L. donovani* from India or from Mediterranean countries.

The above is the first record of the infection of a sandfly of the *major* group with a Mediterranean strain of *L. donovani*. *P. perniciosus* var. *tobbi* should therefore be regarded as a possible vector of kala-azar.

We have to thank Sir Richard Clive, British Minister in Teheran, and Dr. Elgood, Physician to the British Legation in Teheran, for their good offices which made this work possible.

Summary and Conclusions.

The distribution and bionomics of the species of *Phlebotomus* in N.W. Persia are described.

The distribution of *Leishmania* in this area and the possible relations of sandflies to it are discussed.

Observations on the quite distinct and well-defined hours of activity of the different species are recorded.

P. chinensis is recorded from Persia for the first time.

The diagnosis of the female of *P. caucasicus* is established.

P. wenyoni, sp. n., *P. kandelaki*, Schour., and *P. perniciosus* var. *tobbi*, var. n., are described.

A simple method of breeding sandflies while travelling is described.

P. perniciosus var. *tobbi* was infected by feeding on cultures of *L. donovani* of Mediterranean origin.

P. caucasicus was infected by feeding on cultures of *L. tropica*.

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Fig. 1. *Phlebotomus sergenti*.



Fig. 2. *Phlebotomus caucasicus*.

Brush on male genitalia of *Phlebotomus* ($\times 400$).



Fig. 1. *P. caucasicus*.

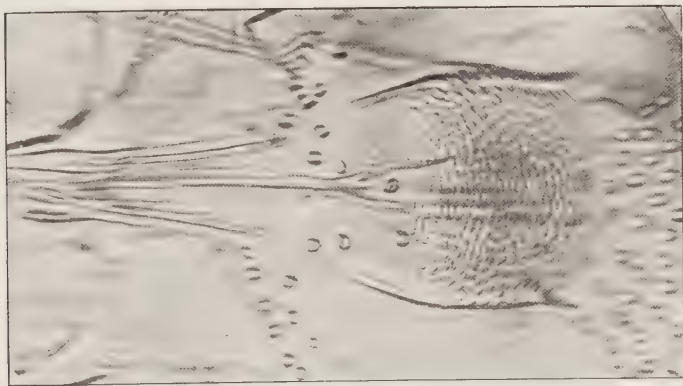


Fig. 2. *P. wenyoni*.

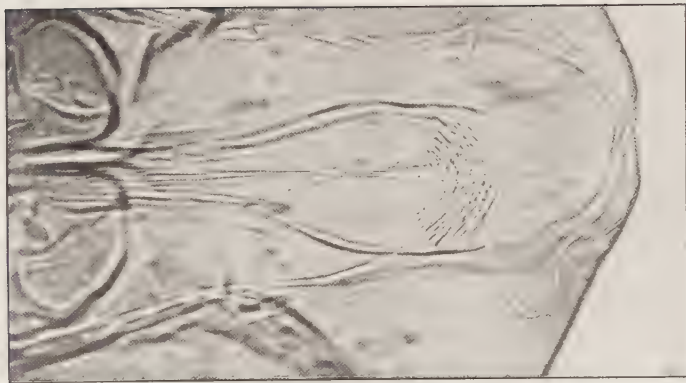


Fig. 3. *P. kandelaki*.

Pharynx of Female *Phlebotomus* ($\times 350$).

MOSQUITO NOTES.—X.

By F. W. EDWARDS.

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- I. Some species of the subgenus *Mansonioides*, Theo.
- II. The Oriental species of *Harpagomyia*.
- III. On the use of the names *Dendromyia* and *Phoniomyia*. W
- IV. A new *Rachionotomyia* from Papua.
- V. A new East African *Anopheles*.

I. SOME SPECIES OF THE SUBGENUS *MANSONIOIDES*, THEO.

The following remarks are based chiefly on the revision of the East Indian species of the subgenus *Mansonioides* just published by J. Bonne-Wepster (Geneesk. Tijds. Ned.-Ind., Deel 70, pp. 940-966, Sept. 1930). A re-examination of the British Museum collection in the light of Mrs. Bonne's work has shown that certain points need elaboration or correction.

I wish to preface these remarks by saying that, after consultation with other specialists, I propose to accept the view that the name *Taeniorhynchus*, Lynch-Arribalzaga, is preoccupied by *Taeniarhynchus*, Weinland; the genus I have called *Taeniorhynchus* therefore becomes *Mansonia*. This change is the less objectionable as the name *Mansonia* has consistently been used for it by Dyar, Martini and others. Martini has recently suggested (Fliegen Pal. Reg. Culic., p. 228) that the larval resemblances between *Mansonioides* and *Coquillettidia* are due to convergence, and that *Mansonioides* has been derived from the *Aedes* stock. If this view were correct it would be necessary to treat the two as a separate genera, but I believe it to be erroneous, and therefore retain both *Mansonioides* and *Coquillettidia* as subgenera of *Mansonia*; the connecting link is provided by the South American subgenus *Rhynchotaenia*.

***Mansonia* (M.) *indiana*, sp. n.**

In several papers the occurrence in the Oriental Region and in Australia of specimens resembling *M. africana* has been mentioned, and under the name *M. africana* Mrs. Bonne gives a full description of this oriental form, her use of the name being based upon an identification made by me of a male specimen submitted by Dr. S. L. Brug. This identification was unfortunately incorrect, and I therefore propose the new name *M. indiana* for the species described by Mrs. Bonne.

Externally *M. africana* and *M. indiana* are very similar, but the latter tends to have the thorax lighter in colour and with less definite markings than in the African form. The two species differ in the genitalia of both sexes. In the male *M. africana* the basal appendage of the coxite (side-piece) terminates in one stout, blunt spine,* whereas in *M. indiana* the spine is replaced by two slender hairs; there are also marked differences in the form of the phallosome. The female *M. africana* has the comb of the eighth tergite very much as figured by Mrs. Bonne, but the eighth sternite (as seen in side view) is deeply emarginate apically, whereas in *M. indiana* it is only somewhat truncate at the tip, scarcely emarginate.

* This structure was not shown in the figure published by me in 1912, but careful observation of a number of mounts shows that it is constantly present; it has been figured correctly by Dyar (Insec. Inscit., xiii, p. 40, 1925).

As type of *M. indiana* I would designate a male in the British Museum from Bandjaran, South Preanger, Java (*S. L. Brug*). The Museum also possesses female specimens which are almost certainly conspecific from Siam (Bangkok, *Ladell*, *Stanton*); India (Gambati, *Mrs. T. B. Fletcher*; Kierpur, Bihar, *Paiva*); Burma (Maymyo, *Major W. Bennett*); Cambodia (Angkor, *Alice Mackie*, per *T. D. A. Cockerell*).

***Mansonia annulipes* (Walker).**

If the rules of zoological nomenclature are to be rigidly followed the name *M. annulipes* (Walker) is preoccupied by *Aedes annulipes* (Meigen), since both species were originally described in *Culex*, and even though both are transferred to other genera the later homonym should not be used. The name *Culex dives* was proposed by Schiner as a substitute, but cannot be used because his notes on the specimen before him show that he had some other species than Walker's *annulipes*. The only other name available is *M. (Culex) longipalpis*, v.d. Wulp; the description of this was incomplete and partly inaccurate (as regards tarsal markings), but the type proves to be this species, as noted by me (*Bull. Ent. Res.*, xv, 1925, p. 260).

***Mansonia bonneae*, sp. n.**

Under the name *M. annulipes* var. A, *Mrs. Bonne* describes a form similar to *M. annulipes* but with several noteworthy differences in the genitalia of the male, and also (if the sexes are correctly associated) of the female. As this form is certainly not a geographical race of *M. annulipes* I should prefer to regard it as a distinct species. The British Museum possesses two males: one from Kuala Lumpur, F.M.S. (*Dr. G. F. Leicester*), the other from Jesselton, North Borneo (*Dr. McGregor*); the former may be regarded as the type.

Externally *M. bonneae* closely resembles *M. annulipes (longipalpis)*, but in the specimens before me the pale scales of the mesonotum have a more pronounced bluish tint, and the scales of the posterior pronotal lobes are fewer and narrower.

***Mansonia septempunctata*, Theobald.**

I have formerly quoted this as a synonym of *M. annulifera*, Theo. (= *M. septempunctata*, Theo.), but as suggested to me by Mr. G. F. Hill this was an error. In my revision of the Australian mosquitos I quoted the name as a doubtful synonym of *M. annulipes*, but this also proves to be incorrect.

A long series recently received from Mr. H. O. C. Littlechild, collected at various localities in Papua, shows that *M. septempunctata* is a valid species. The markings of the mesonotum are much less definite than in *M. annulipes (longipalpis)* and never show any trace of a blue tint; there are also differences in the leg-markings. From *M. indiana* the species differs in being much darker in colour, and from both this and *M. africana* in the form of the eighth sternite of the female, which as seen in side view is somewhat pointed, not at all truncate.

It is probable that the specimens recorded by me from Queensland and Papua as *M. annulipes* and *M. africana*, and those noted by *Mrs. Bonne* from Upper Digoel River, New Guinea, as a variety of *M. africana*, all belong to *M. septempunctata*. Whether the species extends further to the west is not yet certain.

***Mansonia uniformis*, Theo.**

Re-examination of the material only confirms the conclusion previously arrived at regarding the identity of the African, Oriental and Australian forms of this widely spread species. It is probable that *M. marquesensis*, Dyar (*Insec. Inscit.*, xiii, p. 43, 1925; from *Lorenço Marques*) is a synonym of *M. uniformis*, in spite of some discrepancies in the published figures.

II. THE ORIENTAL SPECIES OF *HARPAGOMYIA*.

When revising the genus *Harpagomyia* in 1922 (Trans. Ent. Soc. London, p. 496), I came to the conclusion that there was only one Oriental species, and therefore treated *H. splendens*, de Meij., and *H. coeruleovittata*, Ludlow, as synonyms of *H. genurostris*, Leic. Material recently received from Mr. E. Jacobson from Sumatra has led me to modify this view, and it now appears that as in Africa, so in the Oriental region, there are several slightly different forms of *Harpagomyia*. I have examined males of only one of these (*H. genurostris*), but the distinctions between the females are noted below, and are similar in nature to those between the African species. None of the Oriental species, however, lacks the median silvery stripe of the thorax.

***Harpagomyia genurostris* (Leic.).**

Clypeus yellow, with silvery-white pruinescence. Proboscis yellow except for the swollen tip. Eyes separated by a scaly area which is almost as wide as two facets. Scales on top of head and on pronotal lobes silvery, or with only slight blue tint. Silvery areas on sides of fourth abdominal tergite large.

Specimens from Malay Peninsula (*Leicester* ; *Stanton*) and Ceylon (*James*) appear conspecific. The colour of the thoracic integument is rather variable, some specimens (especially those from Ceylon) being light brown, others darker.

***Harpagomyia splendens*, de Meij.**

Similar to *H. genurostris*, but proboscis black ; clypeus yellowish, with heavy silvery pruinescence. Java.

***Harpagomyia coeruleovittata*, Ludl.**

I have seen no specimens, but according to the original description this Philippine species differs in the " rather long white fuzzy tomentum " on the clypeus.

***Harpagomyia jacobsoni*, sp. n.**

Rather larger than *H. genurostris* or *H. splendens* (wing-length 3.5 mm.). Clypeus black, with slight pruinescence which could not be described as tomentum ; pruinescence heavier on tori. Proboscis yellowish except for the swollen tip. Eyes almost touching, the line separating them without scales. Scales on top of head and on anterior pronotal lobes metallic blue, not silvery white. Silvery areas on fourth abdominal tergite not so large as in the other species.

SUMATRA : Fort de Kock, 1926, 2 ♀♀ (*E. Jacobson*).

Type presented to British Museum by the collector.

III. ON THE USE OF THE NAMES *DENDROMYIA* AND *PHONIOMYIA*.

Dendromyia, Theobald, was formerly treated by Howard, Dyar and Knab as a synonym of *Wyeomyia*, but was restored by Dyar and Shannon as a separate genus, differing from *Wyeomyia* not only in the broader wing-scales but also in the more numerous sternopleural hairs. Very recently it has been claimed by Dr. A. da Costa Lima (Mem. Inst. Oswaldo Cruz, xxiv, p. 35, Aug. 1930) that the type species of *Dendromyia* (*luteoventralis*, Theobald) has been wrongly determined ; that it is in fact the same as *Wyeomyia bromeliarum*, D. & K., and that the name *Dendromyia* should therefore be applied to the group of *Wyeomyia* for which Dyar proposed the name *Pentemyia*. As shown below this conclusion is erroneous, and there is no necessity for any change in the interpretation of the name *Dendromyia*, except that I should prefer to regard it as only a subgenus of *Wyeomyia*.

D. luteoventralis was described from three females from Para, of which one (the type) is still in existence and in good condition. Subsequently Theobald recorded other specimens from Trinidad, British Guiana and Sao Paulo, and figured the wing of one of these females, probably a specimen from Trinidad (Mon. Cul. iii, p. 318). However, a scrutiny of Theobald's series shows that the specimens he referred to *D. luteoventralis* in 1903 belong to two or three different species, but all of them were incorrectly named. The specimen from Trinidad, and some of those from British Guiana, are very probably *W. bromeliarum*, as suggested by Costa Lima. The original type, however, has much broader and denser wing-scales, and (as correctly stated by Bonne & Bonne-Wepster) no trace of white on the tarsi; the sternopleural hairs are rather numerous. The specific identity of *D. luteoventralis* cannot at present be ascertained; it may prove identical with *D. bourrouli*, Peryassu.

Phoniomyia, Theobald, is another generic name about which much confusion exists. The allotment of the name depends upon the identity of the type-species, *P. longirostris*, Theo. In spite of some statements to the contrary, it appears to me that the male and female types of *P. longirostris* are conspecific, both having the abdominal colours conspicuously incised, not separated in a straight line, and wing-scales as in *W. trinidadensis*. Further, I am unable to find any distinction in the types between *P. longirostris*, Theo., and *P. quasilongirostris*, Theo., and consider them conspecific, although Dyar referred the former to *Wyeomyia*, s. str., and the latter to his subgenus *Dodecamyia*.

It seems to me that *Phoniomyia* is a natural group (best regarded as a subgenus of *Wyeomyia*), characterised by having the proboscis as long as the whole body and quite slender, the mesonotal scales more or less metallic, and the scutellar scales silvery. On this definition *Phoniomyia* should include *splendida*, B.-W. & B., *quasilongirostris*, Theo., and *trinidadensis*, Theo., all of which, it may be noted, have larvae of the same type. Whether the larva of the true *P. longirostris* also conforms to this type is not yet certain, owing to various errors of determination and association.

Dyar associated *W. aphobema* with these species in his subgenus *Dodecamyia*, but I do not consider this species belongs to the same group; although its proboscis is rather longer than usual in *Wyeomyia*, it is not so long and slender as in *W. longirostris* and similar species, and the ornamentation is quite different. On the other hand, *Wyeomyia tripartita* as described by Bonne-Wepster & Bonne is evidently similar to the species of *Phoniomyia* as here understood; this species being the type of *Dyarina*, the latter will fall as a synonym of *Phoniomyia*.

IV. A NEW RACHIONOTOMYIA FROM PAPUA.

Rachionotomyia littlechildi, sp. n.

♀. *Head* as seen from in front bright blue, from above greyish, from behind silvery. Clypeus and tori dark brownish, bare. Palpi exceeding clypeus by nearly twice its length. Proboscis long and slender as usual. *Thorax* with the integument almost entirely black, only the pronotal lobes, extreme front margin of scutum and the scutellum light brownish; scutum with a very noticeable steel-blue gloss. Scales of anterior pronotal lobes and scutellum black and broad, of posterior pronotal lobes and scutum black and narrow. Pleurae with a large patch of silvery scales, but mesepimera entirely bare, shining black. *Abdomen* with first tergite silvery grey at sides, dull metallic greenish above; second dull black at sides, leaden-grey above; third and fourth leaden-grey, with lateral basal and apical black triangles; fifth, sixth and seventh leaden-grey above, with large dull black areas laterally towards base. Sternites golden, last few with narrow black basal bands. *Legs* black; front femora in front with a narrow yellow line on basal half, followed by two white streaks; middle femora with a short white line near base, followed by

two white spots; hind femora outwardly with two rather large white patches. *Wings* with the scales on the fork-cells rather broad but not large. Wing-length 3.0-3.8 mm.

PAPUA: Tauri River, Tapala, v.1930, 3 ♀♀ (including type); Aviara Lese, v.1930, 4 ♀♀ (*H. O. C. Littlechild*). Presented to the British Museum by the collector; the localities are "between Yule Island and Port Romilly."

This new species is related to *R. bimaculipes*, differing in the markings of the abdomen and legs, metallic lustre of scutum, and absence of silvery scales on mesepimera. The leaden-grey markings of the abdomen might perhaps be more silvery in fresh examples.

V. A NEW EAST AFRICAN ANOPHELES.

Anopheles (Myzomyia) machardy, sp. n.

Belongs to the *Neomyzomyia* group; most nearly related to *A. ardensis*, Theo., which it resembles in wing-markings and thoracic scaling, but from which it differs as follows: White spots and rings on femora, tibiae and tarsi more numerous and conspicuous; first hind tarsal segment with 10-12 instead of 4-6 white rings. Last two hind tarsal segments entirely white, third segment also white, except for a narrow dark ring at the base.

TANGANYIKA TERRITORY: Amani, 1929 (*J. W. McHardy*); 2 ♂♂, 2 ♀♀ reared from larvae, and presented to the British Museum by the Imperial Institute of Entomology.

According to the collector the larvae closely resemble those of *A. ardensis*, Theo., as described by Hill & Haydon.

OBSERVATIONS ON THE INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE BIONOMICS OF *DYSDERCUS CINGULATUS*, FABR.

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Punjab Agricultural College, Lyallpur, India.

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Introduction.

It is being recognized that for a satisfactory solution of many of the wider problems of Applied Entomology, a study of insect ecology is of paramount importance. It is expected that a knowledge of the factors which influence distribution and abundance of insects will arm economic entomologists better in their warfare against pests. Just recently, Lathrop (1923), Shelford (1927), Buxton (1929), Uvarov (1929), Gryse (1929), and others have shown the importance of meteorological phenomena affecting the development, distribution, and activities of insects. Although our knowledge of the two factors so far studied—temperature and humidity—is far from being complete, still the results so far obtained have proved to be of considerable value. Indeed, instances of the practical application of such knowledge are already available. From his studies on the effects of temperature on household insects, Howard (1896) has shown that cold storage provides an effective control of these pests. Pierce (1916) has correlated the relative advance and retreat of the fall army-worm, *Laphygma frugiperda*, S. & A., with changes in temperature. He maintains that a proper fixation of the zone of effective temperatures may make it possible to alter the sowing time of winter crops to avoid damage from this insect. Barber (1925) explains the decrease of the European corn-borer, *Pyrausta nubilalis*, Hüb., during certain years on the basis of adverse environmental conditions. A. Howard (1921), from his observations in India, states that there exists a definite relationship between termite activity and soil temperature.

As to the influence of humidity, Headlee (1917) has suggested the possibility of checking stored grain pests by altering the humidity within the containers.

The direct influence of seasons—by which we mean the sum total of the climatic complex—on crops is fully recognized, and there is no reason to doubt that the same climatic factors also influence their insect pests, not only through their food-plants, but also directly and independently.

In his report on the failure of the cotton crop in the Punjab in 1919, Milne remarked: "The red cotton bug (*Dysdercus cingulatus*) and the dusky cotton bug (*Oxyacareus lactus*), which are seen in great abundance in normal years, were rarely to be seen this year, especially in the south-western districts of the province." The failure of the cotton crop and the relative scarcity of these insects during these years is such a common and well-marked phenomenon that the farmers in the Punjab have come to regard these two bugs—which the Entomologists consider as pests—as insects of good omen, their abundance bringing in a good cotton crop.

One is thus inclined to ask: What is the correlation between a poor cotton crop and a reduction in the numbers of *Dysdercus*? To elucidate this view has been the object of the work summarised in this paper. Only two explanations appear possible, *i.e.*, either the bugs decrease in numbers because the failing cotton crop does not provide sufficient and suitable nourishment for their sustenance and possibly multiplication, or, the environmental factors responsible for the failure of the cotton crop affect these bugs directly and independently in such a manner as to bring about a reduction in their numbers, or perhaps more correctly, retard the rate of their multiplication. As to the first possibility one may assert that, even when a cotton crop has failed over large areas,* there are always fields, and in some of the worst fields individual plants, showing good growth and providing sufficient wholesome food for the bugs. Thus actually the bugs never exhaust their food supply, and their multiplication is not controlled by this factor. Moreover, the bugs are polyphagous and always have plenty of alternative food-plants for their needs. This leaves us with only one possible explanation, *viz.*, that the climatic factors which bring about cotton failure also adversely affect multiplication of these insects.

This investigation was conducted in the Entomological Laboratories of the Punjab Agricultural College, Lyallpur, India, during the tenure of a Research Studentship (1927-29) awarded by the Indian Central Cotton Committee. The help received from this Committee is gratefully acknowledged.

The writer wishes to express his sense of deep gratitude and indebtedness to Mr. M. Afzal Husain, Entomologist to the Government of the Punjab, for suggesting this problem and for constant help and guidance throughout the course of this investigation. He also kindly placed the resources of the Entomological Section at the disposal of the author. Without his help and useful criticism it would have been impossible to carry out an experimental study of such a technical nature.

An ecological study of this kind requires a very long time for its completion, and a number of interesting lines of investigation had to be discontinued owing to the departure of the writer for Cambridge, on the award of a State Scholarship.

Technique.

In any serious ecological study it is necessary to control and measure accurately the factors which constitute the environment. In the present investigation only two factors—temperature and humidity—have been taken into consideration.

Temperature was controlled by means of electric incubators and refrigerators. Thermographs were used for recording field temperatures.

A good deal of spade-work had to be done in designing an apparatus for control of humidity in closed spaces. After preliminary experiments, ordinary desiccators employed in chemical laboratories were used and humidity controlled by the use of sulphuric acid of different dilutions. Density of sulphuric acid diluted with water was measured with Twaddle's set of hydrometers, and from this the percentage relative humidity at different temperatures was computed by referring to Landolt Bornstein Roth's "Physikalisch-chemische Tabellen."

Duration of the Pre-copulation Period.

Copulation in *Dysdercus cingulatus* is a prolonged affair, and during certain seasons (February-May; August-November) these bugs are met with very commonly in the fields pairing end to end in the usual hemipteran fashion. In this position they continue to feed actively. In captivity the bugs copulate quite readily and freely.

* During years of cotton failure the condition of the crop may be described thus: The plants remain stunted, the leaves turn yellow, then reddish and fall off prematurely; the flowers and young bolls are shed in large numbers; the bolls remaining on the plants do not develop properly, remain soft, open prematurely and badly; the lint is trash, and the seeds are not well developed.

Dysdercus cingulatus does not copulate immediately after the final moult, and usually a considerable time elapses before mating takes place. The duration of this pre-copulation period greatly depends on temperature.

The bugs were reared from the final nymphal stage in the laboratory. The freshly emerged adults were confined in dishes at room temperatures, and during different months of the year the pre-copulation period was noted. It was found that when the temperature ranged from 86–99° F., the pre-copulation period lasted 3–7 days but was prolonged to 15 days when the temperature varied from 77–87° F., and at lower temperature (50–77° F.) the bugs lived for 53–67 days without copulating. It would thus appear that in the colder seasons a longer pre-copulation period is experienced in nature.

Influence of Temperature on Copulation.

To study the influence of different temperatures on copulation the bugs which had been reared in captivity to the adult stage were confined in pairs in glass dishes and subjected to the desired temperature. A temperature of 106° F. is lethal for *Dysdercus cingulatus* adults, death occurring in a few hours (see Table X).

When subjected to a temperature of 103° F., the bugs did not survive for more than a few days. Individuals reared at 90–95° F. were subjected to 103–105° F. in an incubator. They did not copulate, in fact failed to survive for more than 3–4 days, i.e., died within the normal pre-copulation period.

The bugs which had just started copulation were transferred to an incubator at 110° F., and they separated soon after being subjected to this temperature. When exposed to these high temperatures the insects evidently feel very restless and under a feeling of acute discomfort they naturally lose all inclination for mating.

The following Table shows the influence of temperature on the duration of the pre-copulation stage in *Dysdercus cingulatus*.

TABLE I.

Temperature (Fahr.)	Date of transformation into adult	Date of copulation	Pre-copulation period
98–99	13.vii.28	16.vii.28	3–4 days
93–99	14.v.28	20.v.28	5–6 "
*93–95	29.ix.27	4.x.27	5–6 "
95	11.iii.29	14.iii.29	3–4 "
*95	11.iii.29	15.iii.29	4–5 "
86–97	27.viii.28	31.viii.28	5–6 "
86–88	12.x.27	18.x.27	6–7 "
84–87	16.x.27	23.x.27	6–7 "
*86	13.xii.28	21.xii.28	8–9 "
*86	8.i.29	15.i.29	8–9 "
80–88	7.x.27	18.x.27	11–12 "
77–87	10.x.28	25.x.28	14–15 "
74–83	12.iii.29	1.iv.29	19–20 "
70–83	28.ii.29	3.iv.29	32–33 "
70–83	3.iii.29	2.iv.29	29–30 "
69–82	3.iii.29	8.iv.29	35–36 "
55–77	11.xi.28	No copulation	58 days, female died on 9.i.29
55–77	11.xi.28	"	53 " " " 4.i.29
55–77	11.xi.28	"	57 " " " 8.i.29
55–77	11.xi.28	"	67 " " " 18.i.29
50–63	20.xii.28	"	55 " " " 14.ii.29
50–63	20.xii.28	"	60 " " " 19.ii.29
50–63	16.xii.28	"	58 " " " 14.ii.29
50–63	16.xii.28	"	55 " " " 4.ii.29

* Experiments performed in an incubator.

Though copulation occurs in captivity within the temperature range of 62° F. to 100° F., the optimum temperature for this process was found to lie between 72–93° F.

Just as the higher temperatures above 100° F. prevent copulation, cold also inhibits mating, and at 38–40° F., 50–63° F., and 55–77° F. the bugs did not copulate (see Table I). Experiments 17–24, Table I, show that most of the bugs could not tide over the severe winter, and died after about two months. A few surviving ones, however, copulated in March at the advent of a favourable temperature (minimum 40° F., maximum 95° F.).

The dissection of the females that had been kept for a month in the laboratory during winter revealed that the ovaries were quite immature. In the majority of cases even the eggs had not yet differentiated from the primordial germ cells. On the other hand, at 95–99° F. when the pre-copulation period is as short as 3 to 6 days, the females on dissection were found with well-differentiated eggs. The dominant influence of temperature in controlling egg development and copulation in this insect seems evident.

Ordinarily, the bugs remain copulating for a lengthy period. Lefroy (1908) stated that it was usually 36 hours. It is interesting to note that the duration of copulation is also influenced by temperature. Six pairs of bugs were confined at 102° F. in the incubator as soon as they had started copulation. They separated after one hour. At 100° F., such individuals mated for 2–3 hours. The copulation period was prolonged to 10–24 hours at 86–95° F. Finally, at 65–70° F. the bugs remained in continuous copula for 3–5 days. Copulating bugs were also subjected to very low temperatures (36–40° F.), when they became torpid but remained in the usual copulating position; on being transferred to a warmer atmosphere, they became active again and continued copulating. This fact is of significance, because in the Punjab during winter the range of temperature is from 29° F. to 90° F. (1928–29). Thus bugs copulating in the daytime will most probably continue in that position at night also, even when the temperature may be as low as 29° F. to 46° F.

The biological significance of a prolonged coitus is not evident. It seems rather absurd that those bugs should ordinarily spend days joined end to end, one dragging the other, moving about in this uncomfortable position. The aim of the act of copulation is the transfer of sperm, and why the process should take so long is not understood.

Temperature and Oviposition.

Eggs are usually laid in cracks in the soil or under debris lying in the fields. In captivity they are laid freely either at the surface of the soil, if it is provided in the glass breeding dishes, or directly on the glass.

It is some considerable time after copulation that oviposition begins, the duration of this pre-oviposition period primarily depending on temperature. At 95° F. the females usually begin to lay eggs 3–6 days after copulation, and at 70–86° F. they take 13–20 days. It is quite evident that high temperatures would accelerate the development of eggs in the ovaries. The females during summer are laden with mature eggs, whilst at 70–80° F. the ovaries of adults that have lived even for a month consist of undeveloped eggs not ready for deposition.

The influence of temperature on oviposition has already been recognized. Barber (1925) working on the European corn borer, *Pyrausta nubilalis*, Hübn., came to the conclusion "That mean night temperatures of 60° or less were accompanied by a considerably reduced egg-production," and "That a maximum average number of eggs are produced when the average of the mean night temperatures of the period of life of females ranges from 66° F. to 68° F., lower average being accompanied by a marked decrease in the average number of eggs deposited, and higher average temperatures likewise being accompanied by a reduction of the average number of eggs produced." Barber (1926) further maintains that this interference in oviposition may be directly responsible for "determining the abundance of progeny and the intensity of future infestation."

In summarising the influence of temperature on the oviposition response of insects, Richardson (1925) cites a number of interesting cases: "In the alfalfa weevil (*Phytonomus posticus*, Gyll. [*Hypera variabilis*, Hbst.] mean daily oviposition follows in general the curve of mean daily temperature; a similar relation holds for the cotton boll weevil (*Anthonomus grandis*). A reduction of 3° or 4° C. has been observed to lengthen the oviposition period of *Tomicus (Ips) typographicus* L., from 1 to 8 days. A cool night retards the oviposition of *Hypera punctata*, Fab., and it ceases between 7° and 10° C., according to Hudson & Wood (1923). Glenn (1922) states that "Low temperature delays egg-laying of the codling moth (*Carpocapsa pomonella*)"; again, Ross's experiments on the oriental peach moth show that "At low temperatures (below 65° F.) the females will not deposit eggs," and according to Peterson, "At very high temperatures (above 100° F.) oviposition ceases" (Gryse, 1929).

At high temperatures varying from 104 to 107° F. the adult life in the case of *Dysdercus cingulatus* is so short that the bugs do not live long enough to copulate and oviposit (Table IX). Even at 100–103° F. they cannot survive for a period longer than 3–4 days, which is quite insufficient for oviposition. When temperatures range from 90 to 95° F., eggs are soon deposited if fairly high humidity is maintained (70–100 per cent.).

Low temperatures directly check egg-laying, the females refusing to oviposit when the temperature is below 68° F. With a further fall (42–53° F.) during winter, the bugs die without laying eggs.

These facts afford a plausible explanation for the scarcity of these bugs during seasons of extreme cold and heat in the Punjab (December–January and June–August). During the hot months, June–August, the daily maximum temperature in shade ranges from 100° F. to 112° F., and the average relative humidity is 35–70 per cent. The laboratory experiments outlined above show that neither copulation nor oviposition is possible during such adverse environmental conditions, and therefore the insect becomes very scarce. Only rare specimens of the fourth and fifth nymphal instars may be found taking shelter under plants. This state of affairs continues almost till the end of August, when the temperature falls and the bugs begin to copulate and oviposit.

The number of eggs laid varies from 50 to 121. It appears that this number depends largely on the eggs developing simultaneously in the ovarioles.

The following statement (Table II) gives the number of eggs laid at different temperatures. These experiments were performed during the winter. All the bugs used were distended with eggs.

TABLE II.

Constant temperature (Fahr.)	Date of experiment	Date of oviposition	Remarks
107 ...	28.ii.29	—	Female died in 24 hours
104 ...	1.iii.29	—	" "
100 ...	3.iii.29	—	" "
95 ...	2.iii.29	3.iii.29	81 eggs laid
95 ...	8.iii.29	9.iii.29	102 " "
95 ...	8.iii.29	9.iii.29	51 " "
95 ...	7.iii.29	8.iii.29	48 " "
95 ...	10.iii.29	11.iii.29	26 " "
95 ...	11.iii.29	12.iii.29	47 " "
95 ...	5.iii.29	6.iii.29	42 " "
86 ...	13.ii.29	15.ii.29	87 " "
86 ...	21.ii.29	22.ii.29	121 " "
86 ...	13.ii.29	14.ii.29	85 " "
86 ...	13.ii.29	14.ii.29	96 " "
86 ...	20.ii.29	22.ii.29	121 " "
70 ...	18.ii.29	24.ii.29	97 " "
70 ...	26.ii.29	27.ii.29	62 " "
68 ...	26.ii.29	29.ii.29	98 " "
67 ...	22.ii.29	—	No " "
67 ...	22.ii.29	—	" " "

Humidity and Oviposition.

Under suitable temperatures females kept in dishes lay eggs on moist soil. This has been previously observed by Afzal Husain (1927). He also states, "The atmospheric humidity is of no importance, the actual presence of moist surface being a factor essential for oviposition." My observations, however, show that eggs may be laid even on dry soil, when there is enough moisture in the atmosphere. This has been demonstrated by keeping females at known relative humidity. Eggs were deposited in many cases, but only a few representative cases are cited below :—

TABLE III.

Relative humidity	Temperature (Fahr.)	Date of transformation into adults	Date of copulation	Date of oviposition
Per cent.				
100	85-86	8.i.29	15.i.29	20.i.29
91	85-86	15.xii.29	2.i.29	7.i.29
52	82-88	7.x.27	21.x.27	6.xi.27
46	82-88	12.x.27	18.x.27	5.xi.27
62	72-88	10.x.27	—	24.xi.27
42	75-88	8.x.27	—	13.xi.27
40	75-88	14.x.27	—	15.xi.27
62	72-88	10.x.27	—	24.xi.27

It is not essential that the atmosphere be saturated, because any favourable humidity between 40 and 100 per cent. is enough for the deposition of eggs, particularly at suitable temperatures. It has been observed that in the presence of high humidity eggs are laid even if the temperature is maintained at 95° F. Humidity, therefore, is of considerable importance in oviposition. Wardle (1921) has shown that high atmospheric moisture favours oviposition in blowflies, and Adolph (1920) states that it invariably increases the amount of egg-laying in *Drosophila melanogaster*.

Neither high humidity nor deficiency of moisture appears to influence the actual number of eggs laid by an individual, nor does it shorten or lengthen the pre-oviposition period.

Influence of Temperature on Incubation.

In his study of the eggs of *Margaropus annulatus*, Hunter (1908) has pointed out that the incubation period varies inversely with the accumulated effective temperature. Similar results have been recorded by Sanderson (1910) for *Leptinotarsa decemlineata* and *Porthetria dispar*, and by Bodine (1925) for Orthopteran eggs.

A reference to Table IV will show that with a fall in temperature from 95° F. to 58° F. there is a gradual lengthening of the incubation period and that the eggs hatch in 5-6 days when exposed to temperatures fluctuating from 86° F. to 95° F. This range of temperature may be considered as the optimum. The incubation period is prolonged to 10-13 days with temperatures varying from 68° F. to 82° F., and finally at 58-72° F. eggs hatch in 18-26 days. At 38-40° F., alternating with 72-78° F. (daily maximum temperature in sunshine), eggs hatch in 26-34 days.

TABLE IV.

No. of eggs	Relative humidity	Temperature (Fahr.)	Incubation period	Remarks
58	Per cent. 100	38-42	—	Eggs failed to hatch, no orange colour developed
40	100	55-66	—	Eggs failed to hatch, but all developed orange colour indicating that they were fertile
57	91	55-66	—	" " "
37	68	55-66	—	" " "
57	40	55-66	—	" " "
39	95	58-67	25-26 days	Eggs hatched
86	100	68-76	13-14 "	" "
32	70	68-76	13-14 "	" "
29	38	68-76	13-14 "	" "
23	100	68-79	11-12 "	" "
52	84	68-79	11-12 "	" "
51	50	68-79	12-13 "	" "
63	36	68-79	12-13 "	" "
52	32	68-79	—	Eggs failed to hatch
22	22	68-79	—	" " "
67	91	77-82	6 days	Eggs hatched
48	61	72-82	11 "	" "
17	47	72-82	11 "	" "
36	42	74-82	9 "	" "
36	31	72-82	—	Eggs failed to hatch
62	100	83-87	5 "	Eggs hatched
84	65	83-87	5 "	" "
63	42	83-87	5 "	" "
42	36	83-87	5 "	" "
84	32	83-87	—	Eggs failed to hatch
23	38	86-88	5-6 "	Eggs hatched
62	14	86-88	—	Eggs failed to hatch
32	100	88-90	5 "	Eggs hatched
52	75	88-90	5 "	" "
22	60	88-90	5 "	" "
45	100	93-96	5 "	" "
21	91	93-96	5 "	" "

Low temperature leads to high mortality in these eggs. Thus the eggs placed at 32-40° F. for a month in a "Kelvinator" did not hatch at all. On raising the temperature to 53-66° F., the eggs developed an orange colour but failed to hatch, though favourable humidity (40-100 per cent.) was maintained. This orange colour is that of the embryo visible through the transparent chorion. The minimum temperature for egg development is 60° F., if the humidity is favourable (38-100 per cent.). Again, temperatures above 95° F. were found to be fatal for the eggs, and at this temperature eggs only hatch if high humidity (82-100 per cent.) is maintained (Table VI).

In nature temperature is not constant, and besides the daily variations there are other factors which influence it. Cook (1927) has shown that these fluctuations in temperature exert an accelerating influence on the rate of development of insects.

To test the effect of alternating temperatures, preliminary experiments were performed by subjecting eggs to a maximum of 96° F. for 20 to 94 hours and then

removing them to 91° F., the humidity ranging from 65 to 100 per cent. The details of these experiments are given below :—

TABLE V

Relative humidity	Duration of exposure to 96° F.	Remarks
Per cent.		
100	20 hours	Eggs hatched
91	20 "	" "
66	20 "	Eggs failed to hatch
100	40 "	Eggs developed orange colour but failed to hatch
91	40 "	Egg developed faint orange colour but failed to hatch
66	40 "	" " " " " "
100	70 "	" " " " " "
91	70 "	" " " " " "
100	94 "	No orange colour developed and eggs failed to hatch
91	94 "	" " " " " "

Thus eggs exposed for 20 hours at 96° F. and 91–100 per cent. relative humidity hatched in 5–6 days, whilst at 96° F. and 66 per cent. relative humidity they failed to hatch, the exposure remaining the same. From these experiments one concludes that the eggs in the first two cases hatched because they were removed to a more favourable temperature (91° F.) after a brief exposure of 20 hours at 96° F. (zone of fatal temperature for the eggs). Secondly, very high humidity (91–100 per cent.) appears to have compensated for the deleterious effects of high temperature in the first two experiments, and the failure of the eggs to hatch in the third experiment was obviously due to deficient moisture. Again, when the duration of exposure to such conditions was prolonged to 40 hours, the eggs developed a deep orange colour, but later on shrank and failed to hatch. Ultimately, when they were exposed for 70 hours, only a faint change in colour resulted, and an exposure for 94 hours entirely stopped even that much development. Further, eggs when kept at 104° F. and 100 per cent. relative humidity hatched out successfully, if they were exposed to such conditions for 2–20 hours. Beyond this range (107–113° F.) the eggs shrank and failed to hatch. At these temperatures the eggs did not hatch even when the exposure was of a short duration and favourable humidity was maintained. This is, therefore, the zone of fatal temperatures.

Thus we find that eggs can tide over certain high temperatures (100–104° F.) if exposed for a short duration. Even in summer, when the daily maximum temperature is very high, we experience intervals of comparatively low temperatures, e.g., rainy days when the atmosphere cools down temporarily and thus facilitates the incubation of eggs. This fact may explain the presence of young nymphal instars in the fields when the conditions are usually unfavourable for their existence.

Combined Influence of Temperature and Humidity on Incubation.

Barber (1926) noticed in *Pyrausta nubilalis* "That some eggs failed to hatch during protracted dry periods, as of the summer," and he considers this as one of the factors responsible for the decrease in numbers of this insect during certain years. Heat and moisture are closely associated in their influence on the incubation of eggs. For every favourable temperature there is a definite range of humidity at which it is possible for the eggs to hatch. Thus, if eggs of *Dysdercus cingulatus*

are kept at a constant temperature of 95° F. and relative humidity varying from 82 to 100 per cent., they all hatch out in 5 days, but they do not hatch if humidity is kept below 82 per cent. This would be clear from the following table :—

TABLE VI.

No. of eggs	Relative humidity	Constant temperature (Fahr.)	Incubation period	Remarks
	Per cent.			
52	100	95	5 days	Eggs hatched
32	88	95	5 "	" "
34	84	95	5 "	" "
42	82	95	5 "	" "
26	81	95	—	Eggs orange coloured but failed to hatch
30	79	95	—	Eggs failed to hatch
27	70	95	—	" "
52	60	95	—	" "
39	39	95	—	" "

A further set of experiments performed by keeping eggs at 91.4° F. and varying the humidity from 66 to 82 per cent. gave the following results (Table VII) :—

TABLE VII.

No. of eggs	Relative humidity	Constant temperature (Fahr.)	Incubation period	Remarks
	Per cent.			
12	82	91.4	5-6 days	Eggs hatched
25	79	91.4	—	" "
20	75	91.4	—	Eggs failed to hatch
26	66	91.4	—	" "

It will be noticed that eggs hatch out at 95° F. when the humidity is 82 per cent. or above and at 91.4° F. when the humidity is 79 per cent. or above. With the fall in temperature to 88-90° F., the range of effective humidity becomes comparatively wider, till at 83-87° F. it extends from 36-100 per cent. (Table IV), and at 32 per cent. and below eggs do not hatch whatever be the temperature. The accompanying graph (fig. 1) illustrates the relation of combined temperature and humidity to the hatching of eggs in *Dysdercus cingulatus*.

Effects of High Temperature and High Humidity on Nymphs.

Very young nymphs are extremely sensitive to high temperatures, particularly when the humidity is high. First instar nymphs were subjected to humidities varying from 75 per cent. to 100 per cent. at temperatures 95° F., 100° F., and 105° F. Under these conditions they died after three days exposure and in similar conditions the second instar nymphs also failed to survive. At 95° F., starting from the third instar the nymphs reached the adult stage even when the humidity remained high (88 per cent.). At 86° F., the nymphs survived throughout and completed the life-cycle even though the humidity was kept high (Table VIII). It appears therefore that the combined effect of high humidity and high temperatures affords a formidable check on the increase in the numbers of young nymphs.

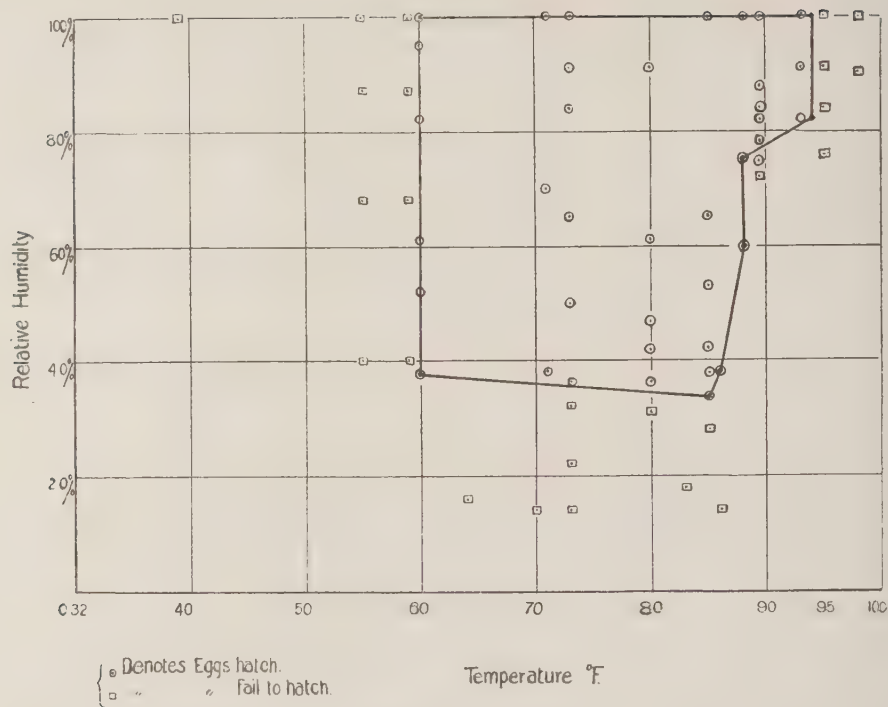


Fig. 1. Relation of temperature and relative humidity to the hatching of eggs of *Dysdercus cingulatus*.

The following Table gives the details of experiments conducted :—

TABLE VIII.

Temperature (Fahr.)	Relative humidity	Date eggs hatched	I Moult	II Moult	III Moult	IV Moult	V Moult	Dura- tion of life cycle	Remarks
	Per cent.								
100-105	100	17.v.28	—	—	—	—	—	—	Nymphs died on 20.v.28
100-105	91	17.v.28	—	—	—	—	—	—	Nymphs died on 20.v.28
100-105	75	18.iii.28	—	—	—	—	—	—	Nymphs died on 21.iii.28
100	100	15.iii.28	—	—	—	—	—	—	Nymphs died on 19.iii.28
100	100	15.iii.28	—	—	—	—	—	—	Nymphs died on 19.iii.28
100	75	15.iii.28	—	—	—	—	—	—	Nymphs died on 19.iii.28
95	100	18.i.28	—	—	—	—	—	—	Nymphs died on 21.i.28
95	88	18.i.28	—	31.i	4.ii	10.ii	13.ii	25 days	First instar nymphs fail to survive
86	88	17.i.28	21.i	24.i	28.i	12.ii	19.ii	32 "	All stages sur- vive

During field observations carried out in July and August 1928, when humidity ranged from 64 to 100 per cent. and the maximum temperature remained above 100° F., the nymphs were found in small numbers. Later on, however, when the temperature came down to 90–95° F. and the rains had also stopped, the nymphs appeared in larger numbers and were fairly common in the fields, suggesting that the survival was greater under these conditions.

Effects of Low Humidity and High Temperature on Nymphs.

There are very few insects, if any, that can live without the aid of moisture. The nymphs of *Dysdercus cingulatus* are particularly sensitive in this respect. The increased rate of evaporation caused by dry air at a high temperature brings about what has been termed "desiccation rigour." It has been observed that moisture deficiency at high temperatures proves fatal for the first two instars. Experiments were performed at temperatures varying from 81 to 85° F. and 99 to 100° F., with low humidity (17–37 per cent.), and it was found that the younger nymphs had failed to survive. These laboratory experiments were confirmed by extensive field study. It was observed in May and June 1928, that the first three nymphal instars had almost disappeared from the fields, only the fourth and fifth instars being common. The disappearance of the early instars may be explained by the fact that they had developed into the later stages. This is partly true, but it is difficult to explain the total absence of early instars on this supposition. Since the eggs also fail to hatch under similar climatic conditions stated above, it is possible that this may also account for the absence of these nymphal instars. The last two stages in the life-cycle of the bug are comparatively hardy, as has been proved by exposing them to low humidity (17–42 per cent.) and temperatures of 95° F. to 100° F. When subjected to high temperatures (106–113° F.) and 50–100 per cent. relative humidity even the fifth instar nymphs did not survive.

The duration of the nymphal period was found to depend on temperature. Experiments were conducted by rearing newly hatched nymphs at varying temperatures and humidity. It was found that at 58–78° F. the life-cycle concluded in 73 days. When, however, the temperature rose to 62–68° F., this period was reduced to 47–49 days. Finally at 82–86° F. the life-cycle took 32–37 days.

Effects of Temperature and Humidity on Adult *Dysdercus*.

Extensive field study showed that from September to February 1927–28 the bugs fed on cotton. From February onwards they were collected underneath debris mainly composed of fallen leaves and bolls of cotton. Late in March and April 1928, they moved to the two Malvaceous plants, *Malva parviflora* and *Althaea rosea*. In May, they began to climb up the silk-cotton tree (*Bombax malabaricum*). This tree fruits during the spring, and in May and June a large number of fruits fall down and the bugs with them, each fruit carrying with it from 10 to 20 bugs. A temporary refuge was sought for by these insects on grasses and other wild plants. The insect during this period exhibits seasonal oligophagy inasmuch as it starts feeding up on a wide range of host-plants but later restricts itself to only a few allied host species. In July, the bugs were collected from *Hibiscus esculentus*, on the green pods of which they continued to live and feed till the cotton bolls appeared.

The seasonal calendar reproduced on p. 558 (fig. 2) shows the distribution of *Dysdercus cingulatus* on different host-plants during various months of the year.

A very interesting point observed in this field study was that during May, June, July and August, the bugs were very rare in the cotton fields and were present only in small numbers on the silk-cotton trees. It was also observed during this period that no eggs were laid. The meteorological record suggested that this paucity of bugs could be correlated with the prevailing low humidity and high temperature.

prolonged to 5-10 days when the variation in temperature ranged from 93 to 100° F. At 55-79° F. the adults lived longest, *i.e.*, 75-93 days. As the temperature dropped to 50-63° F. the bugs became mostly inactive, and in several cases died, after 40-67 days. Very severe winter inhibits activity, and the bugs remain practically torpid.

The Punjab during the winter of 1928-29 experienced a severe cold wave. This afforded an opportunity of studying more closely the behaviour of *Dysdercus cingulatus* in the field when the temperature varied from 26° F. to 36° F. Field observations were verified by artificially maintaining the same conditions in the laboratory. It was noticed that the bugs remained inactive at 40-59° F. On being exposed for four days to 36-40° F. in a "Kelvinator" they remained in catalepsis and failed to recover completely even on exposure to sun-light and favourable temperatures (70-76° F.). But when this exposure to low temperatures was reduced to three days, the insects completely revived and resumed activity. The adults were also subjected to temperatures below freezing point, the exposure varying from 5 to 24 hours. After 5 hours exposure the insects regained activity on being transferred to favourable temperatures but failed to do so if the exposure was longer than 5 hours. It was observed that even on days when the temperature ranged from 30 to 50° F., the bugs were active during the warmer part of the day and copulating pairs could be seen in the fields when the temperature in the sun was only 60-70° F. To study this behaviour of the insects, the field conditions were maintained artificially. The insects were kept in dishes at 100 per cent., 60 per cent., 40 per cent. relative humidity and exposed to low temperature (36-40° F.) at night, and during the day they were placed in the sun at 72-76° F. It was observed that these bugs remained in catalepsis during the night in low temperatures and revived during the day. Not only that, but they copulated and oviposited as well when the temperature during the day remained favourable.

TABLE IX.

Exp.	Temp. (Fahr.)	Relative humidity	Date of transformation into adult	Date adult died	Adult life in days
		Per cent.			
1 ...	50-60	50	20.xii.29	14.ii.29	54
2 ...	50-63	100	16.xii.28	11.ii.29	55
3 ...	50-63	37	19.xii.28	11.ii.29	52
4 ...	55-77	58	11.xi.28	18.i.29	67
5 ...	55-77	37	11.i.28	4.i.29	53
6 ...	55-77	15	11.xi.28	9.i.29	58
7 ...	55-79	65	9.xii.27	10.iii.28	93
8 ...	58-88	67	16.x.27	8.i.28	82
9 ...	58-88	52	19.x.27	7.i.28	78
10 ...	72-88	62	10.x.27	25.xi.27	54
11 ...	78-88	52	5.x.27	10.xi.27	35
12 ...	81-88	34	13.x.27	31.x.27	18-19
13 ...	86-93	38	25.iv.28	5.v.28	8-10
14 ...	95	30	14.iii.29	22.iii.29	5-11
15 ...	93-100	75	30.iv.28	11.v.28	5-10
16 ...	101-102	17	8.v.28	10.v.28	3-4
17 ...	101-105	17	23.v.28	25.v.28	2-3
18 ...	106-107	100	6.vii.28	6.vii.28	3-5 hours
19 ...	106-107	37	6.vii.28	6.vii.28	2-4 "

Prolonged exposure to a dry atmosphere during the summer tends to withdraw moisture from the bodies of these bugs and leads to their speedy death (Table IX, Experiments 16-17). This was ascertained by keeping bugs at a constant temperature and known moisture. At temperatures varying from 90 to 100° F. and a relative

humidity of 5–20 per cent., the bugs lived only 3–5 days and during this period did not lay any eggs. It has been observed in the preceding pages that the nymphs also are extremely susceptible to arid conditions, particularly during summer when the temperature ranges from 95° F. to 110° F. Thus it will appear that *Dysdercus*, in spite of constantly sucking plant-sap and the contents of the cotton seeds, is unable to regulate its moisture supply when such adverse climatic conditions prevail. Headlee (1913) found in the case of *Toxoptera* that it developed at the same rate at 80° F. and varying relative humidity, suggesting that a sap-feeding insect may be relatively independent of the direct influence of the atmospheric humidity. The influence of low humidity on different stages in the life-cycle of *Dysdercus* has been recognised in the preceding pages, and it is evident that favourable humidity (40–100 per cent.) is necessary for the multiplication and, in general, the survival of this insect. Ballard (1928) working on *Dysdercus sidae* states that a short spell of hot and dry weather is accompanied by a diminution in the numbers of this bug. Cowland & Rutledge (1927) in their notes on *Dysdercus* in the Sudan have made similar observations. "It is believed that during this period, from January to June, if the season is unusually hot and dry, many of the colonies become extinct." The evidence suggests therefore that dry air at high temperatures considerably inhibits activity and ultimately brings about the death of this insect.

Conclusions.

Experiments conducted and observations made go to prove that temperature and humidity are the two main factors which control the abundance of *Dysdercus cingulatus*. Field observations prove that the younger nymphs and adults are almost absent during May, June, July and August. The paucity of bugs during these months is due to low humidity and high temperatures, which influence all those functions of an insect on which increase in number depends, *i.e.*, copulation, oviposition, incubation of eggs, and the life of the nymphal and adult stages. As the season advances and the favourable temperatures set in, there is again a gradual increase in the numbers of this insect. Then there is a resumption of activity and the various vital processes begin to function. The approach of cold weather, again, has a retarding influence on metabolism, the longer period of adult life in winter naturally spreads oviposition over a relatively longer period, and besides even the egg-bound females refuse to deposit eggs. There is thus a marked decrease in the numbers of this bug following a severe spell of cold weather.

Milne states that during 1919–21 the cotton failed in the Punjab because of low humidity and high temperature prevailing and there was a corresponding decrease in numbers of *Dysdercus cingulatus*. If so, then the plant and the pest independently suffered from the same adverse climatic conditions.

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